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TIPULOIDEA OF THE TONGARIRO NATIONAL PARK AND OHAKUNE DISTRICT, NEW ZEALAND (DIPTERA)

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ONE TEXT FIGURE

INTRODUCTION

The detailed knowledge of the crane flies of the immediate vicinity of Ohakune and Mount Ruapehu, Wellington Province, New Zealand, that has now become available through the untiring efforts of Mr. Thomas R. Harris and a few other collectors, well warrants the publication of a list of the species.

The first specimens that were received from the vicinity of Ruapehu were collected by Mr. Morris N. Watt in January, 1921, along the trail to the mountain hut on the southwest side of the mountain. The flies were taken in the zone of silver beech (*Nothofagus menziesii* Hooker f.) and included the following species: *Macromastix ferruginosa ruapehuensis, Discobola tesselata, Zelandomyia raupehuensis, Z. watti, Gynoplistia* (*Cerozodia*) *hudsoni hemiptera, Ceratocheilus ochraceum,* and *Molophilus latipennis.* All of the species described by the writer were based either wholly or in part on Mr. Watt's material. In late December, 1921, and early January, 1922, Mr. Watt and Mr. Cuthbert C. Fenwick again visited Ruapehu, this time on the northern side, and collections were made in the vicinity of their camp at an approximate altitude of 3,700 feet, where the beech forest, tussock land, and alpine scoria begin to intermingle with one another. The Tipulidæ collected at this time included the following undescribed forms: *Molophilus flagellifer, M. niveicinctus,* and *Amphineurus gracilisentis,* as well as sev-

eral species that had been previously described and are recorded later in the present paper. The various excursions undertaken by Harris to the camp on Ruapehu are discussed under the second part of this paper. The few crane flies that were taken in this region by Hudson in 1912 were listed the following year.[1] Hudson's second trip to Ruapehu, in company with his daughter, Miss Stella Hudson, in 1922, included a few additional novelties that were taken in the vicinity of the Whakapapa camp on the northern side of Ruapehu at an approximate altitude of 3,700 feet, and have been described by Edwards; these are *Macromastix bivittata, M. elongata,* and *Gynoplistia* (*Gynoplistia*) *orophila.*

The first Harris collections that were received by the writer were kindly sent by Dr. James W. Campbell, and included only a few miscellaneous species that had been taken by Harris in the vicinity of Ohakune in 1919 and 1920. Strange to say, these desultory collections included a few species, chiefly of the genus *Gynoplistia,* that were not rediscovered during the subsequent systematic combing of the region by Mr. Harris, beginning in the early spring of 1921 and continued until 1926. These various Harris collections, made in the near vicinity of Ohakune and in Tongariro Park on Mount Ruapehu constitute the basis for the present list. A simple expression of thanks for the untiring efforts of Mr. Harris in making known the fascinating tipulid fauna of New Zealand seems but inadequate reward for the long hours spent afield and at home preparing the material. The writer can honestly state that never has he enjoyed such capable coöperation in the development of a local faunal list and such intelligent appreciation of the problems to be met as has come from Mr. Harris, to whom all credit is given for the results obtained during this study. This abundant material has rendered the writer's task a comparatively easy one.

GEOGRAPHICAL LIMITS ADOPTED IN THE PRESENT REPORT

Mr. Harris has suggested the following geographical limits, which are herein adopted: "I would reckon the Ohakune district to extend from Waimarino, 18 miles to the north (of Ohakune), to Waiouru, 17 miles to the south, and back to Mount Ruapehu. You then have a natural boundary of tussocks and plain on both sides." (See fig. 1.) Acting upon this suggestion, the writer has adopted a circular area having an

[1] Trans. N. Z. Inst. 45 (1913) 57–67.

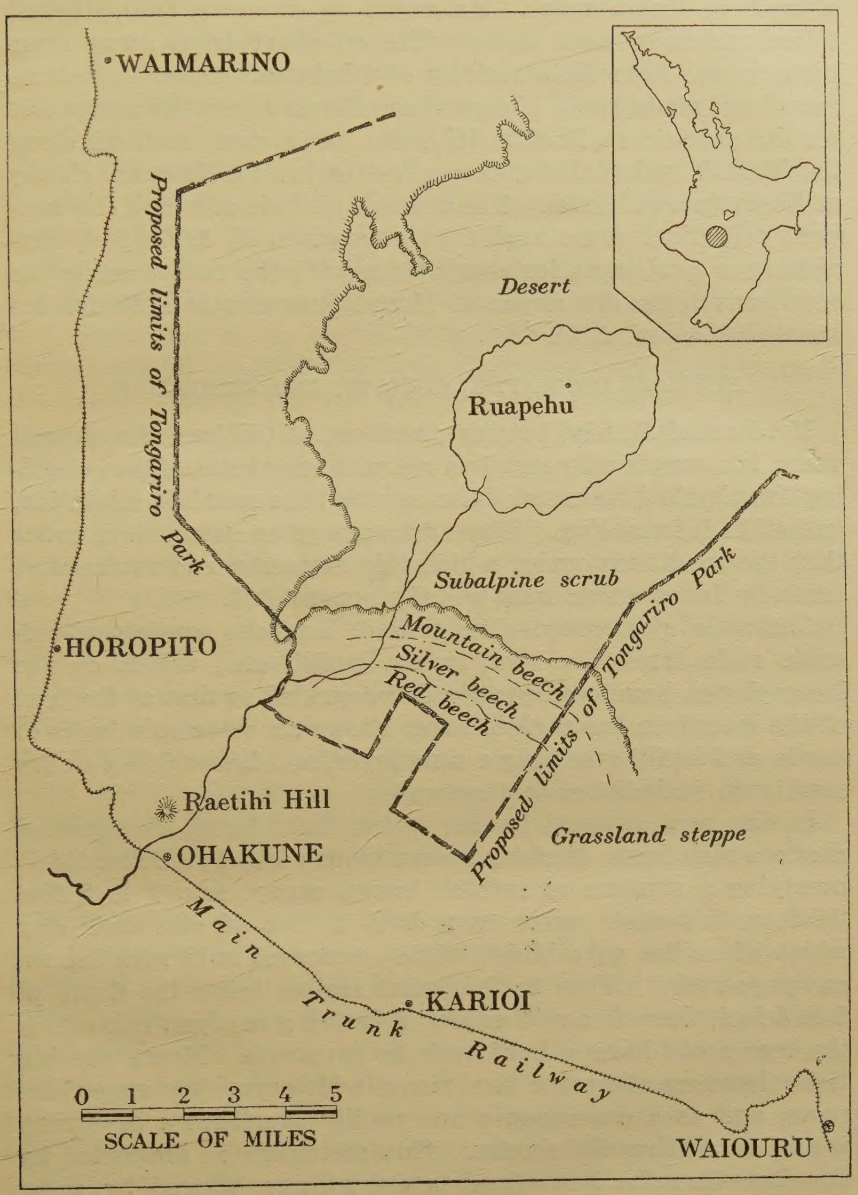

FIG. 1. Ohakune district and Toongariro Park, North Island, New Zealand. The location and the area of the park are indicated by the shaded circle in the index map.

18-mile radius from Ohakune as a center, thus including approximately 1,000 square miles, although the actual area upon which collections have been made presumably would not include

a tenth of that amount. As might be expected, the principal collections have been made while on short trips away from home in the immediate vicinity of Ohakune. Other collections have been made along Mangawhero River, along the slopes and on the summit of Raetihi Hill, and at various stations along the Main Trunk Railway from Waimarino to Waiouru, chiefly at Horopito and Karioi. The average altitude at which the Ohakune collections were made has been given as 2,060 feet, furnishing a good basis for comparison with the rather numerous specimens from the slopes of Mount Ruapehu at altitudes between 3,000 and 4,500 feet.

PHYSICAL GEOGRAPHY, CLIMATE, AND VEGETATION

Mr. Randal Mundy, botanist, resident of Ohakune for several years, has very kindly supplied me with instructive data regarding the physical features of the country, the rainfall, insolation, and other information. These data are given herewith in order that the conditions under which this abundant and remarkable crane-fly fauna exists may be fully appreciated.

Character of country.—The cone of Ruapehu consists of volcanic rocks, andesitic lava, scoria, lapilli, etc., which, on the lower slopes, have been greatly disintegrated so that at the base of the mountain the surface cover shows an outer thin layer of scoria and lapilli overlying a sand layer, and below this a clayey sand with included rock fragments.

In the area covered by the mixed rain forest, the ground shows a rich, loose, blackish brown humus soil, 1 to 2 feet thick, overlying a stratum of reddish brown sandy clay, 1 to 2 feet thick, which again rests upon 3 to 4 feet of stiff buff clay which often lies on a bluish white calcareous mud rock known as "papa-rock." Thus in the forest region, below the depth of 3 to 4 feet, there is a stiff subsoil forming a hardpan into which the tree roots have a hard task to penetrate. Hence the big trees have no taproots but many wide-spreading superficial roots, and as a consequence are readily overthrown by strong winds or earthquake shocks. This statement is supported by the fact that the bush floor is everywhere littered by great fallen trunks showing all stages of decay and making progress through the forest an arduous task.

Rainfall.—Twenty-five years ago (about 1904) all the land around Ohakune was densely forested and had an annual rainfall of nearly 100 inches in the neighborhood of the numerous hill ridges. North of Ohakune for a distance of 9 miles, the

virgin forest is still intact save for the depredations of wandering cattle, and this hummocky bushed area probably has a rainfall of 80 inches or more annually, the rain being fairly equally distributed throughout the year. In the cleared areas the rainfall is much lower. The fall for the years 1919 to 1921 was as follows: 1919, 41.42 inches; 1920, 59.7 inches; 1921, 50.92 inches. This total of 152.04 inches gives an average of 50.7 inches annually for the open township free from bush.

Seasons.—The climate of the Ohakune Plateau is a mild temperate one. The four seasons are experienced here but are not so well-marked as in colder latitudes. Summer temperatures range from 70° to 80° F. or over; the heavy bush is cooler than the open. Spring and fall are mild and pleasant. Winter is never very severe, the mercury rarely falling below 20° F.; but, owing to the high elevation and frequent clear skies, keen night frosts occur in winter and, at times, in spring and fall. These hoar frosts are common in the open cleared land, early in the morning, with the formation of perpendicular ice prisms upon the ground surface. There are usually very few snowfalls about Ohakune. In 1920 there were but two snowfalls, one of 4 or 5 inches, the other of about 2 inches, which were soon melted by the sun. In 1921 there was a single snowfall of about 2 inches. Harris kept a detailed weather report from May, 1922, to May, 1923, and this indicates frosty days from April through September. This fact and the account of winter conditions in the bush, discussed below, becomes of great value in a consideration of the winter crane flies discussed under a later caption.

Winds.—The prevailing wind is from the west or northwest and it brings heavy rain. South winds bring cold. Easterly (east and northeast) winds bring clear skies and fine, dry days.

Insolation.—At the elevation of Ohakune, the heating power of the sun's rays is very great, even in winter, but after sunset there is a sudden drop in the temperature. The proportion of sunny days is high. In summer, daylight lasts from 4 a. m. to 8.30 p. m. In winter it lasts from about 6.30 a. m. to 5 p. m.

Winter conditions in the bush.—In the tall, thick rain forest, owing to the close, overhead foliage cover of the great taxad trees, extremes of temperature are not felt, and throughout the year the forest temperature is fairly equable. In the coldest part of winter, when all the cleared land may be enduring hard frosts, the forest interior has the appearance of a vast conservatory stocked with healthy green vegetation and with no sign

of frost except where, owing to a fall of trees, the bush floor lies open to the sky. In the bush, too, there is no general leaf fall at the cold season of the year, the trees, shrubs, and herbs (with the exception of the fuchsias and ground orchids) retaining their foliage throughout the winter and shedding it almost imperceptibly long after the following spring has clothed them with foliage. Thus, even in the coldest weather, in the shelter of the bush, the lower forms of animal life are not subjected to very rigorous conditions.

Vegetation.—It is well-known that crane flies are lovers of rich vegetation, usually near running or standing water. Definite groups or associations of crane-fly species are found to frequent equally definite plant societies or associations, and this interrelationship is often well marked. No serious attempt can be made to correlate insect societies without a careful study of the plant associations, and for this reason, a general account of the vegetation of the places where the Harris collections were made is given. The notes are based on extensive data sent me by Mr. Randal Mundy, to whom my sincere thanks are extended. For more-detailed accounts of the plant ecology, the student is referred to three recent and comprehensive reports.[2]

The lower levels of the Ohakune section, at altitudes ranging from 2,000 to 3,000 feet, support a dense, lofty, evergreen, mixed rain forest that almost rivals a semitropical forest in its luxuriance. Above the 3,000-foot contour, however, the character of the forest changes, the mixed forest giving way to the beech forest which extends to the mountain hut on the base of Ruapehu (4,550 feet).

The mixed rain forest.—Seen from the open at a distance of half a mile, the rain forest shows a fairly even contour line about 80 to 90 feet above the ground and stands out as a rather somber, sepia-tinted mass of foliage. Seen closer, the forest has a dark yellow-green color, caused by the dominance of the great taxad trees—rimu (*Dacrydium cupressinum*), matal (*Podocarpus spicatus*), miro (*P. ferrugineus*), kahikatea (*P. dacrydioides*), and totara (*P. totara*)—which reach an average height of 80 to 90 feet, though individual trees may be more than 100 feet in height. These characteristic trees grow intermixed and make up the great bulk of the forest, forming the sheltering

[2] Cockayne, L., Vegetation of New Zealand (1921) 1–364 and Report on a Botanical Survey of the Tongariro National Park (1908) 1–42.—Kensington, W. C., Forestry in New Zealand (1909) 1–118.

top cover. All other tree species are merely secondary in the composition of the forest and have to fit themselves in as best they can among the big conifers.

On entering the shady, humid "bush" one is bewildered by its dense lush greenery which shuts out all view beyond a distance of 20 to 30 yards. One notes that the tree heads are arranged approximately in three tiers of foliage. The first, or upper, tier is formed by the tall conifers, as given above; the second tier consists of the heads of trees 40 to 60 feet high; for example, hinau, pokaka, black maire, *Weinmannia racemosa,* tawa, and *Griselinea littoralis;* the third tier, averaging from 20 to 30 feet in height, usually shows intermixed *Melicytus ramiflorus, Carpodetus serratus, Pittosporum colensoi, Aristotelia racemosa, Fuchsia excorticata, Nothopanax arboreum, N. colensoi, N. edgerleyi, Schefflera digitata, Pseudopanax crassifolium, Myrine salicina,* and *Pennantia corymbosa.*

Below these three tiers of trees occur several species of shrubs, varying in height from 5 to 15 feet, the commonest of which are *Drimys colorata, D. axillaris, Melicope simplex, Myrtus pedunculata, Nothopanax anomalum, Leucopogon fasciculatus, Suttonia divaricata, Coprosma grandifolia, C. robusta, C. tenuifolia, C. lucida, C. rotundifolia, C. rhamnoides, C. foetidissima, Brachyglottis, Paratrophis,* and *Alseuosmia macrophylla.* In addition, there is a plentiful sprinkling of handsome tree ferns, from 4 to 20 feet high, of the four species *Cyathea dealbata, Dicksonia fibrosa, D. squarrosa,* and *Hemitelia smithii.*

The ground cover consists chiefly of big tufts of a coarse fern, *Lomaria discolor,* or, in very damp places, of dense tufts of harsh *Polystichum vestitum* ferns, along with many tufts of the beautiful single- or double-crape ferns, *Todea hymeno-phylloides* and *T. superba.* In better-illuminated areas the ground is covered with clumps of bush grass, and in the intervening spaces grow filmy ferns, mosses, and hosts of *Coprosma* seedlings. There are, in addition, many lianes and epiphytes, giving to the bush vegetation a somewhat tropical appearance.

The upper beech forest.—Four and one-half miles up the Ruapehu track, at an elevation of about 2,900 feet, the large trees of the mixed forest gradually disappear, giving way to an almost pure beech forest, which extends for another four and one-half miles to the mountain hut at an altitude of 4,550 feet on the lower slopes of Ruapehu. This beech forest is composed of four species which follow one another, in a rather indefinite

zonal arrangement, as one approaches the mountain. Thus, where the mixed forest reaches its upper limit, big trees of *Nothofagus solandri* become common and these are succeeded in turn by belts of *N. fusca, N. menziesii,* and *N. cliffortioides,* the last species reaching, with gradually dwindling height, to the mountain hut. At about 3,000 feet *Libocedrus bidwillii* puts in an appearance, and is scattered throughout the beech zones up to the 4,500-foot level. At the 3,100-foot contour nearly all of the tree and shrub species of the lower mixed forest have disappeared and a new assemblage of small trees and shrubs appears among the beeches; thus we find as characteristic species an abundance of *Nothopanax colensoi, Phyllocladus alpinus, Coprosma cuneata, Dacrydium biforme, D. bidwillii, D. colensoi, D. intermedium, Nothopanax simplex, N. parvum, Coprosma foetidissima, Griselinia littoralis,* and the big tufted sedge *Gahnia pauciflora.*

The trail to the mountain hut extends from Ohakune station through the three beech zones and subalpine conditions to the hut itself. The vegetation in the vicinity of the hut consists of shrubby mountain beech (*N. cliffortioides*), certain Epacridaceæ (*Dracophyllum* spp.), and grasses. The details of the subalpine Tipulidæ are given in the following section.

Mr. Mundy writes that Harris gathers most of his material by sweeping with his net the low underscrub of the forest, this including the various *Coprosma* species, *Leucopogan fasciculatus,* the ferns, *Lomaria discolor* and *Polystichum vestitum,* crape ferns, *Melicytus ramiflorus, Nothopanax, Drimys,* and bush grass.

SEASONAL DISTRIBUTION

Nothing has been recorded concerning the seasonal appearance of crane flies in any country in the Southern Hemisphere, and consequently the following data that have been derived from the present study are of especial value. As a basis for comparison, available records for the mountain hut and beech zones on Ruapehu, the higher slopes and summit of Raetihi Hill, and the red beech forest at Karioi are given. A special caption on Winter Tipuloidea is supplied.

MOUNT RUAPEHU

Ruapehu is an old volcano, supposed to be extinct, but still showing some thermal activity in the form of a hot lake at the bottom of its old crater. It is 9,175 feet above sea level, or approximately 7,000 feet higher than the Ohakune Plateau.

There are a few glaciers and snow upon the upper 2,000 feet of the summit region all the year round, but in winter the snow line descends to about the 5,000-foot contour line. The lower slopes of Ruapehu are deeply gullied, and from the radiating gullies many small rivers pour down. One of these, the Mangawhero, flows through Ohakune.

In order to compare the lower altitudes and rain-forest conditions obtaining near Ohakune, the material taken in the near vicinity of the mountain hut (4,550 feet) and along the trail to the hut (3,000 to 4,000 feet) by Harris and Watt is summarized. The latter collections are especially valuable as including the zones of red beech (*Nothofagus fusca*), silver beech (*N. menziesii*), and mountain beech (*N. cliffortioides*); the last as a narrow belt between 3,700 and 4,000 feet, but with stunted trees to the hut.

Harris made four trips to the mountain hut (February 25–28, 1922; January 12–15, 1923; January 4–6, 1924; January 20–21, 1924). It is rather unfortunate that no very fine weather was experienced by Harris on any of these trips, and the material that was taken was almost invariably the result of hurried collections between showers or at short intervals between violent wind storms.

January (midsummer) records from near the mountain hut (4,000 to 4,500 feet) in the zone of low scrub and grass steppe.

Dolichopeza atropos.
Macromastix ferruginosa ruapehuensis.
Macromastix fucata.
Limonia (Dicranomyia) annulifera.
Limonia (Dicranomyia) megastigmosa.
Limonia (Dicranomyia) sperata.
Limonia (Dicranomyia) weschei.
Discobola ampla.
Austrolimnophila argus.
Metalimnophila mirifica.
Zelandomyia penthoptera.
Zelandomyia ruapehuensis.
Zelandomyia watti.
Ischnothrix connexa.
Elephantomyia ruapehuensis.
Elephantomyia zealandica.
Aphrophila neozelandica.
Molophilus flagellifer.
Molophilus harrisianus.
Molophilus irregularis.
Molophilus latipennis.
Molophilus morosus.
Molophilus pulcherrimus.
Molophilus uniplagiatus.
Amphineurus (Amphineurus) lyriformis.
Amphineurus (Amphineurus) senex.
Amphineurus (Nesormosia) fatuus.
Amphineurus (Nothormosia) gracilisentis.
Amphineurus (Nothormosia) harrisi.

The record of species taken along the trail, chiefly in the beech zones, is more extensive than the above, and is especially

valuable as a basis for comparison with the lower beech zones at Karioi, and the summit of Raetihi Hill.

January (midsummer) records along the track to the hut (3,000 to 4,000 feet), through the beech forests (Nothofagus spp., Libocedrus, and others).

Paracladura macrotrichiata.
Dolichopeza parvicauda.
Macromastix ferruginosa ruapehuensis.
Macromastix holochlora.
Macromastix viridis.
Macromastix lunata.
Limonia (Zelandoglochina) harrisi.
Limonia (Zelandoglochina) huttoni.
Limonia (Zelandoglochina) melanogramma.
Limonia (Dicranomyia) multispina.
Limonia (Dicranomyia) reversalis.
Limonia (Dicranomyia) seducta.
Discobola ampla.
Discobola tesselata.
Rhamphophila sinistra.
Austrolimnophila argus.
Austrolimnophila chrysorrhœa.
Austrolimnophila leucomelas.
Austrolimnophila marshalli.
Austrolimnophila nigrocincta.
Austrolimnophila oculata.
Austrolimnophila subinterventa.
Heterolimnophila truncata.
Metalimnophila mirifica.
Metalimnophila protea.
Zelandomyia ruapehuensis.
Zelandomyia watti.
Gynoplistia (Paralimnophila) skusei.
Gynoplistia (Gynoplistia) fimbriata.
Gynoplistia (Gynoplistia) lobulifera.
Gynoplistia (Gynoplistia) pleuralis.
Gynoplistia (Cerozodia) hudsoni hemiptera.
Atarba filicornis.
Elephantomyia ruapehuensis.
Elephantomyia zealandica.
Ceratocheilus ochaceum.
Aphrophila flavopygialis.
Molophilus bidens.
Molophilus flagellifer.
Molophilus irregularis.
Molophilus latipennis.
Molophilus oppositus.
Molophilus uniplagiatus.
Amphineurus (Amphineurus) hudsoni.
Amphineurus (Amphineurus) lyriformis.
Amphineurus (Amphineurus) senex.
Amphineurus (Nesormosia) fatuus.
Amphineurus (Nothormosia) gracilisentis.
Amphineurus (Nothormosia) harrisi.
Amphineurus (Nothormosia) insulsus.

RAETIHI HILL

The following observations are by Mr. Randal Mundy:

This steep ridge, which forms a part of the southern boundary of the Tongariro National Park, lies close to Ohakune and rises to the height of 2,933 feet, or nearly 1,000 feet above the Ohakune Plateau. The rather extensive summit is fairly level and shows an almost vertical escarpment of friable limestone rock. Both the slopes and the summit are densely

timbered, bearing the trees and shrubs that are characteristic of the tall mixed forest at the 2,000-foot level. However, on the slopes, large contorted rata trees (*Metrosideros robusta*) appear in great numbers, intermixed with the big taxads, although they are almost absent from the forest at the base of the ridge; moreover, on the summit, many fine trees of *Libocedrus bidwillii* are met with, just as they are at the 3,000-foot level in the beech woods four and one-half miles up the Ruapehu track. Tree ferns are fairly common all the way up the ridge but are at their best on the lower slopes where some specimens of *Cyathea dealbata* and *Hemitelia smithii* have trunks 10 to 15 feet high. There is also a sprinkling of *Dicksonia squarrosa* but only an occasional *Dicksonia fibrosa*, although the latter is very common in the damp area at the base of the ridge.

On the summit occur fairly big trees of rimu, matai, miro, totara, rata, and *Libocedrus* but not growing so close together as in the forest below; black maire (*Olea cunninghamii*) is present in fair quantity; many *Weinmannia racemosa* trees; *Nothopanax arboreum* and *N. colensoi*, together with many of their seedlings; *Myrsine salicina;* much *Brachyglottis repanda;* a fair number of small-sized *Carpodetus serratus;* numerous small *Fuchsia* trees; a few low shrubs of *Pennantia corymbosa;* some *Melicytus ramiflorus;* shrubs of *Alseouosmia macrophylla* fairly common; in damp places, some young shrubs of *Schefflera digitata;* several big *Drimys colorata;* many small *Aristotelia racemosa;* many shrubs of *Coprosma grandifolia*, and, especially, of *C. tenuifolia* and *C. fœtidissima*, these three latter species forming most of the undershrub; big patches of *Lomaria discolor*, and, in damp places, of *Polystichum vestitum*, the tufts of these two latter species forming a great part of the ground color; many tufts of single- and double-crape ferns; plenty of bush grass; abundance of mosses; plenty of *Asplenium bulbiferum;* many filmy ferns on the ground and on old logs.

Harris visited Raetihi Ridge on December 13 and 14, 1922, and collected in greater detail on November 20 and 30, 1923, and April 8, 1924.

November (late spring) records from the summit and the higher slopes of Raetihi Ridge.

Paracladura lobifera.
Dolichopeza parvicauda.
Macromastix atridorsum.
Macromastix fucata.
Limonia (Zelandoglochina) paradisea circumcincta.
Limonia (Zelandoglochina) huttoni.
Limonia (Zelandoglochina) melanogramma.
Limonia (Dicranomyia) annulifera.
Limonia (Dicranomyia) cuneipennis.
Limonia (Dicranomyia) gubernatoria.
Limonia (Dicranomyia) multispina.
Limonia (Dicranomyia) reversalis.
Limonia (Dicranomyia) semicuneata.
Limonia (Dicranomyia) subfasciata.
Limonia (Dicranomyia) tarsalba.
Discobola picta.
Discobola tesselata.

November (late spring) records from the summit and the higher slopes of Raetihi Ridge—Continued.

Rhamphophila sinistra.
Tinemyia margaritifera.
Austrolimnophila argus.
Austrolimnophila chrysorrhœa.
Austrolimnophila geographica.
Austrolimnophila marshalli.
Austrolimnophila nigrocincta.
Austrolimnophila stemma.
Acantholimnophila maorica.
Heterolimnophila truncata.
Metalimnophila howesi.
Metalimnophila unipuncta.
Gynoplistia (Gynoplistia) sackeni.
Atarba filicornis.
Atarba viridicolor.
Molophilus flagellifer.
Molophilus hexacanthus.
Molophilus tenuistylus.
Amphineurus (Amphineurus) hudsoni.
Amphineurus (Nothormosia) gracilisentis.
Amphineurus (Nothormosia) harrisi.
Amphineurus (Nothormosia) insulsus.

April (fall) records from the summit and the slopes of Raetihi Ridge (records based on the collection made April 8, 1924).

Paracladura obtusicornis.
Paracladura macrotrichiata.
Limonia (Zelandoglochina) cubitalis.
Discobola tesselata.
Amphineurus (Nesormosia) fatuus.
Amphineurus (Nothormosia) gracilisentis.
Amphineurus (Nothormosia) insulsus.

KARIOI

The following observations on conditions at Karioi are by Mr. Mundy:

Karioi lies about 6 miles eastward of Ohakune and here the forest ends, giving place to open, grassy, pumice plains. The Karioi "bush," at an elevation of 2,100 to 2,200 feet, consists of beech woods, with *Nothofagus fusca* as the dominant tree, but intermixed with many trees of *N. menziesii*. Within the woods, a damp low drainage area is found where the bush soil is water-logged and consequently contains the plant species that can endure such conditions; for example, *Fuchsia*, *Schefflera*, and *Polystichum vestitum*, the last named being very abundant, with the tufts nearly touching. When fairly in this damp portion, no tufts of the common *Lomaria discolor* are found, its place being taken by the *Polystichum*. No taxad trees (rimu, matai, miro, etc.) are found, and black maire and hinau likewise seem to be absent, but a few young contorted pokakas are present. Tawa, *Pennantia*, and *Paratrophis* are absent and the only species of tree fern to be seen is *Dicksonia fibrosa*, which is here in great numbers. Many of Harris's crane flies were swept from the crowded clumps of *Polystichum* and others from beneath the dead, drooping fronds of *Dicksonia*.

Collections made in the red-beech forest (Nothofagus fusca) at Karioi.

EARLY SPRING (NOVEMBER 7, 1923)

Mischoderus annuliferus.
Macromastix atridorsum.
Limonia (Zelandoglochina) cubitalis.
Limonia (Zelandoglochina) huttoni.
Limonia (Zelandoglochina) melanogramma.
Limonia (Dicranomyia) luteipes.
Limonia (Dicranomyia) multispina.
Limonia (Dicranomyia) reversalis.
Limonia (Dicranomyia) tarsalba.
Discobola tesselata.
Tinemyia margaritifera.
Austrolimnophila argus.
Austrolimnophila cyatheti.
Austrolimnophila hudsoni atripes.
Austrolimnophila geographica.
Acantholimnophila maorica.
Limnophila quaesita.
Gynoplistia (Gynoplistia) luteicincta.
Gynoplistia (Gynoplistia) sackeni.
Atarba viridicolor.
Trimicra inconstans.
Molophilus flagellifer.
Molophilus flavidulus.
Molophilus howesi.
Molophilus multicinctus.
Molophilus plagiatus.
Molophilus sublateralis.
Molophilus sylvicolus.
Amphineurus (Amphineurus) hudsoni.
Amphineurus (Nothormosia) harrisi.
Amphineurus (Nothormosia) insulsus.

FALL (APRIL 14, 1924)

Paracladura macrotrichiata.
Paracladura obtusicornis.
Limonia (Dicranomyia) gubernatoria.
Limonia (Dicranomyia) tristigmata.
Limonia (Dicranomyia) vicarians.
Nothophila fuscana.
Molophilus luteipygus.
Amphineurus (Nothormosia) gracilisentis.
Amphineurus (Nothormosia) harrisi.
Amphineurus (Nothormosia) insulsus.
Amphineurus (Nothormosia) nothofagi.

WINTER TIPULOIDEA

The open winters, with few snowfalls and killing frosts, enable a number of spring and fall species to persist into or even throughout the winter months. A few additional species, moreover, are eminently characteristic of the winter season. These are indicated by an asterisk in the accompanying list. Especially noteworthy are the species of *Paracladura,* the various *Macromastix,* and the magnificent *Gynoplistia hiemalis.*

Paracladura complicata.
Paracladura lobifera.
Paracladura maori.
Paracladura obtusicornis.
Zelandotipula novaræ.
* *Macromastix binotata.*

* *Macromastix halterata.*
* *Macromastix longioricornis.*
* *Macromastix monstrata.*
* *Macromastix sessilis.*
* *Macromastix simillima.*
Limonia (Zelandoglochina) cubitalis.
Limonia (Dicranomyia) ægrotans.
Limonia (Dicranomyia) luteipes.
Limonia (Dicranomyia) sulphuralis cholorophylloides.
Limonia (Dicranomyia) vicarians.
Limonia (Dicranomyia) weschei.
Discobola ampla.
Discobola tesselata.
Gynoplistia (Paralimnophila) skusei.
* *Gynoplistia (Gynoplistia) hiemalis.*
* *Gynoplistia (Gynoplistia) ocellifera.*
Gynoplistia (Gynoplistia) sackeni.
Ischnothrix connexa.
Molophilus flavidulus.
Molophilus multicinctus.
Molophilus macrocerus.
Molophilus tanypus coloratus.
Amphineurus (Nothormosia) gracilisentis.
Amphineurus (Nothormosia) harrisi.
Amphineurus (Nothormosia) insulsus.

There are several additional species of *Macromastix* in New Zealand that are characteristic winter species, but these have not yet been taken in the Ohakune district.

ANNOTATED LIST OF SPECIES

In the accompanying list the families and the genera are arranged in their phylogenetic sequence, so far as this can be determined at present from a study of the adults alone. Species are arranged alphabetically under each genus. A majority of the species were originally described from material taken within the faunal limits of the district; each name of such species is followed by an asterisk. For a common species with numerous records a range of dates is given, since to give only the two extremes would be highly misleading as to whether the species concerned was actually double brooded or had an unusually wide seasonal distribution. The approximate altitude of all Ohakune records is 2,060 feet.

TANYDERIDÆ

1. MISCHODERUS ANNULIFERUS (Hutton).

Tanyderus annuliferus HUTTON, Trans. N. Z. Inst. 32 (1900) 48–49.

The commonest species of the genus. Numerous specimens from Ohakune, mostly taken by beating in the bush; occurs almost throughout the growing season: October 27, 1921; November 16, December 1 and 31, and February 18, 1922; March 11, 1923. In beech forest, Karioi, November 7, 1923.

2. MISCHODERUS FORCIPATUS (Osten Sacken).

Tanyderus forcipatus OSTEN SACKEN, Verh. zool.-bot. Gesell. Wien for 1879, 29 (1880) 520.

"Found hanging on small bushes near edge of creek. Found only on two or three nights, but on one night they were fairly numerous. They were sluggish and easily caught while hanging by a leg or two to the bushes, mostly low down."—*Harris.* Ohakune, October 20, 1921.

TRICHOCERIDÆ

3. PARACLADURA APERTA (Alexander).*

Trochocera aperta ALEXANDER, Insec. Inscit. Menst. 10 (1922) 198–199.

Type locality: Ohakune, May 7, 1922. No additional material taken.

4. PARACLADURA COMPLICATA Alexander.*

Paracladura complicata ALEXANDER, Insec. Inscit. Menst. 12 (1924) 13.

Type locality: Ohakune, May 10, 1923.

5. PARACLADURA LOBIFERA (Alexander).

Trichocera lobifera ALEXANDER, Insec. Inscit. Menst. 10 (1922) 146–147.

Ohakune, November 14–16, 1922, beating in bush; June 13, 1923. Raetihi Hill, November 10, 1923.

6. PARACLADURA MACROTRICHIATA (Alexander).*

Trichocera macrotrichiata ALEXANDER, Insec. Inscit. Menst. 10 (1922) 199.

Type locality: Ohakune, April 10, 1922. Karioi, in beech forest, April 14, 1924. Raetihi Hill, April 8, 1924. Ruapehu, altitude 4,000 feet, January 4, 1924.

7. PARACLADURA MAORI (Alexander).

Trichocera maori ALEXANDER, Insec. Inscit. Menst. 9 (1921) 159–160.

Ohakune, May 16, 1923; July, 1921.

8. PARACLADURA OBTUSICORNIS (Alexander).*

Trichocera obtusicornis ALEXANDER, Insec. Inscit. Menst. 10 (1922) 146.

Type locality: Ohakune, July, 1921. Ohakune, May 2–10, 1923. Karioi, in beech forest, April 14, 1924. Raetihi Hill, April 8, 1924.

TIPULIDÆ

TIPULINAE

Tribe TIPULINI

9. DOLICHOPEZA (DOLICHOPEZA) ATROPOS (Hudson).

Tipula atropos HUDSON, Trans. N. Z. Inst. 27 (1895) 295.

Ohakune, November 18, 1922. Ruapehu, 4,500 feet, February 26, 1922. "Caught these at night with a light; they occurred in a damp spot where a small creek flowed over moss into a larger one; one individual flew and settled low down on the trunk of a tree, head up, all legs on support, wings spread out."—*Harris.*

10. DOLICHOPEZA (DOLICHOPEZA) PARVICAUDA Edwards.

Dolichopeza parvicauda EDWARDS, Trans. N. Z. Inst. 54 (1923) 330–331.

Ohakune, November 3, 1921; November 14–22 and December 1–5, 1922. Raetihi Hill, 2,800 feet, December 14, 1922; November 20–30, 1923. Ruapehu, beech zone, 3,000 to 4,000 feet, January 12, 1923.

11. ACRACANTHA (AUSTROTIPULA) HUDSONI (Hutton).

Pachyrhina hudsoni HUTTON, Trans. N. Z. Inst. 32 (1900) 24–25.

Ohakune, January 8, 1923. "Swampy patch in open." *Harris.*

12. ZELANDOTIPULA NOVARÆ (Schiner).

Tipula novaræ SCHINER, Reise der Novara, Dipt. (1868) 37.

Ohakune, October 14–27, 1921; October 18–25, November 20–23, and February 3, 1922; March 17, 1924; April 30, 1923; May 3, 1922; July, 1921. "When at rest usually hold wings folded over back but sometimes outspread. Occur in many situations on fences, walls, bushes, etc."—*Harris.*

13. MACROMASTIX (AUROTIPULA) BIVITTATA Edwards.*

Macromastix bivittata EDWARDS, Ann. & Mag. Nat. Hist. IX 11 (1923) 629–630.

Type locality: Waimarino and Kaitoka, January, 1922 (*Hudson*).

14. MACROMASTIX (AUROTIPULA) DUX (Kirby).

Tipula dux KIRBY, Trans. Ent. Soc. London (1884) 270–271.

Ohakune, March 7, 1923.

15. MACROMASTIX (AUROTIPULA) FERRUGINOSA RUAPEHUENSIS Alexander.*

Macromastix ferruginosa ruapehuensis ALEXANDER, Ann. & Mag. Nat. Hist. IX 11 (1923) 208.

Type locality: Ruapehu, 4,000 to 5,000 feet, January, 1921 (*Watt*). Ruapehu, 4,000 to 4,500 feet, January 20, 1924 (*Harris*).

16. MACROMASTIX (CHLOROTIPULA) ELONGATA Edwards.*

Macromastix elongata EDWARDS, Ann. & Mag. Nat. Hist. IX 11 (1923) 630–631.

Type locality: Whakapapa, Ruapehu, 3,700 feet, January 9, 1922 (*Stella Hudson*).

17. MACROMASTIX (CHLOROTIPULA) HOLOCHLORA HOLOCHLORA (Nowicki).

Tipula holochlora NOWICKI, Beitr. zur Kenntniss der Dipt. Neuseelands (1875) 9.

Ohakune, December 13, 1922. Ruapehu, beech forest, 3,000 to 4,000 feet, January 12, 1923.

17a. MACROMASTIX (CHLOROTIPULA) HOLOCHLORA ANGUSTIOR Alexander.*

Macromastix holochlora angustior ALEXANDER, Ann. & Mag. Nat. Hist. IX 12 (1923) 212.

Type locality: Ohakune, December 31, 1922, to January 5, 1923.

18. MACROMASTIX (CHLOROTIPULA) VIRIDIS (Walker).

Tipula viridis WALKER, Ins. Saundersiana, Dipt. (1856) 445.

Ohakune, October 27–29, 1921; October 18–29, 1922; November 6–15, 1921; November 26 and January 11, 1922. Raetihi Hill, 2,800 feet, December 14, 1922. Ruapehu, beech zone, 3,000 to 4,000 feet, January 20, 1924. "February, 1922—Common for some time past on walls, bushes, and fences. When at rest, the wings are held spread out. Have reared them from pupæ found in decaying wood."—*Harris.*

19. MACROMASTIX (MACROMASTIX) ALBIPLAGIA ALBIPLAGIA Alexander.*

Macromastix albiplagia ALEXANDER, Ann. & Mag. Nat. Hist. IX 11 (1923) 202–203.

Type locality: Ohakune, January 18 to February 14, 1922. Ohakune, February 3, 1922.

19a. MACROMASTIX (MACROMASTIX) ALBIPLAGIA OBLITERATA Alexander.*

Macromastix albiplagia obliterata ALEXANDER, Ann. & Mag. Nat. Hist. IX 11 (1923) 203–204.

Type locality: Ohakune February 9–16, 1922. "February 24, 1922—These are very plentiful at present; about fifty on the walls of the house at dusk to-night, holding on with all the legs, the wings outspread. They also rest on bushes, weeds, grass, etc., and are rather quick in flight. They flutter actively about, probably seeking their mates."—*Harris.*

20. MACROMASTIX (MACROMASTIX) ANGUSTICOSTA Alexander.*

Macromastix angusticosta ALEXANDER, Ann. & Mag. Nat. Hist. IX 11 (1923) 110–111.

Type locality: Ohakune, December 23, 1921.

21. MACROMASTIX (MACROMASTIX) ATRIDORSUM Alexander.*

Macromastix atridorsum ALEXANDER, Ann. & Mag. Nat. Hist. IX 9 (1922) 314–315.

Macromastix harrisi ALEXANDER, Ann. & Mag. Nat. Hist. IX 10 (1922) 98–99.

Spring. Type locality: Ohakune, October 10 and November 13, 1921. Karioi, in beech forest, November 7, 1923; very common and variable. Raetihi Hill, 2,800 feet, November 20–30, 1923.

22. MACROMASTIX (MACROMASTIX) BINOTATA Hutton.

Macromastix binotata HUTTON, Trans. N. Z. Inst. 32 (1900) 32.

Late fall and winter. Ohakune, May 11–30, 1922; May 16 and June 13, 1923. "These are the first of the winter tipulids. The males are found on fences during the daytime, legs and wings outspread. The nearly wingless females were found in the mill, around stacked timber, not far above the ground following a hard frost. One isolated female laid 258 eggs. Thinking that possibly I might find them mating at night, I spent an hour and a half searching the same place one night last week. I came across one female about four feet above the ground, the highest I have yet found them. The numerous blackish eggs are very hard so one could walk on them on the ground without breaking them."—*Harris.*

23. MACROMASTIX (MACROMASTIX) FLAVIDIPENNIS Alexander.*

Macromastix flavidipennis ALEXANDER, Ann. & Mag. Nat. Hist. IX 11 (1923) 201–202.

Type locality: Ohakune, January 28, 1922.

24. MACROMASTIX (MACROMASTIX) FUCATA Hutton.

Macromastix fucata HUTTON, Trans. N. Z. Inst. 32 (1900) 31.

Mount Ruapehu, January 1, 1922 (*C. C. Fenwick*). Raetihi Hill, 2,800 feet, November 20, 1923.

25. MACROMASTIX (MACROMASTIX) HALTERATA Alexander.*

Macromastix halterata ALEXANDER, Ann. & Mag. Nat. Hist. IX 11 (1923) 109–110.

Late fall and winter. Type locality: Ohakune, July, 1921; May 21–28, 1922. Ohakune, May 7–11, 1922; May 10 and June 13, 1923; July 17, 1923, in bush. "I get this species flattened out on the large leaves of shrubs in the bush; when at rest both wings and legs are spread wide apart."—*Harris.*

26. MACROMASTIX (MACROMASTIX) HUTTONI Edwards.

Macromastix huttoni EDWARDS, Trans. N. Z. Inst. 54 (1923) 342–343.

Summer. Ohakune, November 16, 1921; January 7–18 and February 8, 1922.

27. MACROMASTIX (MACROMASTIX) LONGIORICORNIS Alexander.*

Macromastix longioricornis ALEXANDER, Ann. & Mag. Nat. Hist. IX 11 (1923) 108–109.

Late fall and winter. Type locality: Ohakune, July, 1921; May 17, 1922.

28. MACROMASTIX (MACROMASTIX) LUNATA LUNATA Hutton.

Macromastix lunata HUTTON, Trans. N. Z. Inst. 32 (1900) 32.

Summer. Ohakune, November 25, 1922; December 25, 1921; December 1–17, 1922. Raetihi Hill, December 14, 1922. Ruapehu, beech zone, 3,000 to 4,000 feet, January 12–15, 1923.

28a. MACROMASTIX (MACROMASTIX) LUNATA FUSCOLATERA Alexander.

Macromastix lunata fuscolatera ALEXANDER, Ann. Ent. Soc. America 15 (1922) 236.

Type locality: Ruapehu, 4,000 to 5,000 feet, January, 1921 (*Watt*).

29. MACROMASTIX (MACROMASTIX) MONSTRATA Alexander.*

Macromastix monstrata ALEXANDER, Ann. & Mag. Nat. Hist. IX 13 (1924) 522–523.

Winter. Type locality: Ohakune, July 17, 1923.

30. MACROMASTIX (MACROMASTIX) OHAKUNENSIS Alexander.*

Macromastix ohakunensis ALEXANDER, Ann. & Mag. Nat. Hist. IX 11 (1923) 204–205.

Type locality: Ohakune, December 25, 1921.

31. MACROMASTIX (MACROMASTIX) SESSILIS Alexander.*

Macromastix sessilis ALEXANDER, Ann. & Mag. Nat. Hist. 13 (1924) 379–380.

Type locality: Ohakune, May 10, 1923.

32. MACROMASTIX (MACROMASTIX) SIMILLIMA Alexander.*

Macromastix simillima ALEXANDER, Ann. & Mag. Nat. Hist. IX 13 (1924) 521–522.

Winter. Type locality: Ohakune, August 10, 1922. Owhango, July 1, 1922. Waiouru, June 11, 1923.

33. MACROMASTIX (MACROMASTIX) SINCLAIRI Edwards.

Macromastix sinclairi EDWARDS, Trans. N. Z. Inst. 54 (1923) 350.

Taihape, common, March 5, 1923.

34. MACROMASTIX (MACROMASTIX) SUBMANCA Alexander.*

Macromastix submanca ALEXANDER, Ann. & Mag. Nat. Hist. IX 12 (1923) 112.

Early spring. Type locality: Ohakune, October 19, 1922.

35. HUDSONIA ÆNIGMATICA Alexander.*

Hudsonia ænigmatica ALEXANDER, Ann. & Mag. Nat. Hist. IX 17 (1926) 547–548.

Type locality: Ohakune, January 31, 1924.

LIMONIINÆ

Tribe LIMONIINI

36. LIMONIA (ZELANDOGLOCHINA) CUBITALIS (Edwards).

Dicranomyia cubitalis EDWARDS, Trans. N. Z. Inst. 54 (1923) 275–276.

Common, especially in the spring and fall, in the bush lingering into the winter. Ohakune, October 15–24 and November 18, 1921; April 4, May 17, and July 11–17, 1923. Waiouru, May 26, 1923. Karioi, in beech forest, November 7, 1923. Raetihi Hill, 2,800 feet, April 8, 1924. Ruapehu, February 25, 1922. "Get these at night, hanging on small bushes in the forest."—*Harris.*

37. LIMONIA (ZELANDOGLOCHINA) HARRISI (Alexander).*

Dicranomyia harrisi ALEXANDER, Ann. & Mag. Nat. Hist. IX 12 (1923) 195–196.

Type locality: Ohakune to the mountain hut on Ruapehu, 3,000 to 4,000 feet, January 12, 1923. Ohakune, December 31, 1922.

38. LIMONIA (ZELANDOGLOCHINA) HUTTONI (Edwards).

Dicranomyia huttoni EDWARDS, Trans. N. Z. Inst. 54 (1923) 276.

Spring and early summer. Ohakune, November 14 and December 5, 1922. Karioi, in beech forest, November 7, 1923. Raetihi Hill, November 30, 1923; December 14, 1922. Ohakune to mountain hut on Ruapehu, 3,000 to 4,000 feet, January 12, 1923.

39. LIMONIA (ZELANDOGLOCHINA) MELANOGRAMMA (Edwards).

Dicranomyia melanogramma EDWARDS, Trans. N. Z. Inst. 54 (1923) 276–277.

Spring and early summer. Ohakune, November 14 and December 1–13, 1922. Karioi, in beech forest, November 7, 1923. Raetihi Hill, 2,800 feet, November 30, 1923. Ohakune to mountain hut on Ruapehu, beech zone, January 12, 1923.

40. LIMONIA (ZELANDOGLOCHINA) PARADISEA CIRCUMCINCTA (Alexander).*

Dicranomyia paradisea circumcincta ALEXANDER, Ann. & Mag. Nat. Hist. IX 13 (1924) 561–562.

Type locality: Summit of Raetihi Hill, 2,800 feet, November 20–30, 1923.

41. LIMONIA (DICRANOMYIA) ÆGROTANS (Edwards).

Dicranomyia ægrotans EDWARDS, Trans. N. Z. Inst. 54 (1923) 280–281.

Spring and fall. Ohakune, October 10–29 and November 1–15, 1921; December 4, 1922; April 4 and May 16, 1923. Taihape, May 19, 1923.

42. LIMONIA (DICRANOMYIA) ANNULIFERA (Alexander).

Dicranomyia annulifera ALEXANDER, Ann. & Mag. Nat. Hist. IX 10 (1922) 87.

Raetihi Hill, summit, 2,800 feet, November 20, 1923.

43. LIMONIA (DICRANOMYIA) BROOKESI (Edwards).

Dicranomyia brookesi EDWARDS, Trans. N. Z. Inst. 54 (1923) 281.

Ohakune, October 20, 1921.

44. LIMONIA (DICRANOMYIA) CUNEIPENNIS (Alexander).*

Dicranomyia cuneipennis ALEXANDER, Ann. & Mag. Nat. Hist. IX 12 (1923) 99–100.

Type locality: Ohakune, November 16, 1922. Raetihi Hill, 2,800 feet, November 20, 1923.

45. LIMONIA (DICRANOMYIA) DIVERSISPINA (Alexander).*

Dicranomyia diversispina ALEXANDER, Ann. & Mag. Nat. Hist. IX 12 (1923) 197–198.

Type locality: Ohakune, October 31, 1922.

46. LIMONIA (DICRANOMYIA) FASCIATA (Hutton).

Dicranomyia fasciata HUTTON, Trans. N. Z. Inst. 32 (1900) 34.

A single female, Ohakune, November 13, 1922.

47. LIMONIA (DICRANOMYIA) GUBERNATORIA (Alexander).

Dicranomyia gubernatoria ALEXANDER, Ann. & Mag. Nat. Hist. IX 13 (1924) 363–364.

Karioi, in beech forest, April 14, 1924. Raetihi Hill, 2,800 feet, November 30, 1923.

48. LIMONIA (DICRANOMYIA) HETERACANTHA (Alexander).*

Dicranomyia heteracantha ALEXANDER, Ann. & Mag. Nat. Hist. IX 11 (1923) 195.

Type locality: Ohakune, January 28, 1922.

49. LIMONIA (DICRANOMYIA) LUTEIPES (Alexander).*

Dicranomyia luteipes ALEXANDER, Ann. & Mag. Nat. Hist. IX 12 (1923) 196–197.

Type locality: Ohakune, November 18, 1921; December 10, 1922. Ohakune, May 16 and June 13, 1923. Karioi, in beech forest, November 7, 1923. The allotype female was associated with *Limonia* (*Dicranomyia*) *torrens* near a waterfall.

50. LIMONIA (DICRANOMYIA) MEGASTIGMOSA (Alexander).

Dicranomyia megastigmosa ALEXANDER, Ann. & Mag. Nat. Hist. IX 10 (1922) 557–558.

Ruapehu, 4,500 feet, February 26, 1922; January 14, 1923; January 20, 1924. "On underside of rocks in creek; wings folded over back when at rest."—*Harris.* This crane fly is a characteristic mountain species. It is very closely allied to *L.* (*D.*) *sperata* Alexander, and the exact relationships between the two are still uncertain.

51. LIMONIA (DICRANOMYIA) MŒSTA (Alexander).*

Dicranomyia mœsta ALEXANDER, Ann. & Mag. Nat. Hist. IX 11 (1923) 193–194.

Type locality: Ohakune, February 8, 1922.

52. LIMONIA (DICRANOMYIA) MULTISPINA (Alexander).*

Dicranomyia multispina ALEXANDER, Ann. & Mag. Nat. Hist. IX 9 (1922) 509–510.

Type locality: Ohakune, October 1, 1921. Ohakune, November 14 and December 31, 1922; January 5, 1923. Karioi, in beech forest, November 7, 1923. Raetihi Hill, 2,800 feet, November 30, 1923. Ruapehu, beech zone, 3,000 to 4,000 feet, January 12, 1923.

53. LIMONIA (DICRANOMYIA) NEPHELODES (Alexander).*

Dicranomyia nephelodes ALEXANDER, Ann. & Mag. Nat. Hist. IX 10 (1922) 84–85.

Type locality: Ohakune, September 30 to October 27, 1921.

54. LIMONIA (DICRANOMYIA) NIGRESCENS (Hutton).

Dicranomyia nigrescens HUTTON, Trans. N. Z. Inst. 32 (1900) 34.

Ohakune, September 25, 1922; "taken at night, hanging over water."—*Harris.*

55. LIMONIA (DICRANOMYIA) PUNCTIPENNIS MAORIENSIS (Alexander).*

Dicranomyia punctipennis maoriensis ALEXANDER, Ann. & Mag. Nat. Hist. IX 12 (1923) 98.

Type locality: Ohakune, October 10, 1922; November 6–13, 1921. Taihape, October 18, 1922. "Taken in daytime in a swampy bulrush patch in open."—*Harris.*

56. LIMONIA (DICRANOMYIA) PENDULIFERA (Alexander).

Dicranomyia pendulifera ALEXANDER, Ann. & Mag. Nat. Hist. IX 12 (1923) 379–380.

Ohakune, October 11 and November 16, 1921.

57. LIMONIA (DICRANOMYIA) REPANDA (Edwards).

Dicranomyia repanda EDWARDS, Trans. N. Z. Inst. 54 (1923) 278.

A spring species. Ohakune, October 1–21 and November 8–13, 1921; October 31 to November 16, 1922.

58. LIMONIA (DICRANOMYIA) REVERSALIS (Alexander).*

Dicranomyia reversalis ALEXANDER, Ann. & Mag. Nat. Hist. IX 9 (1922) 507–508.

Type locality: Ohakune, October 10, 1921. Taihape, October 12, 1921. Karioi, in beech forest, November 7, 1923. Raetihi Hill, 2,800 feet, November 30, 1923. Ruapehu beech zone, January 12, 1923.

59. LIMONIA (DICRANOMYIA) SEDUCTA (Alexander).*

Dicranomyia seducta ALEXANDER, Ann. & Mag. Nat. Hist. IX 11 (1923) 97–98.

Type locality: Ohakune, December 25, 1921. Ohakune, December 1–31, 1922. Ruapehu, beech zone, 3,000 to 4,000 feet, January 12, 1923. "These rest on spider webs; legs outspread; wings folded over body."—*Harris.*

60. LIMONIA (DICRANOMYIA) SEMICUNEATA (Alexander).*

Dicranomyia semicuneata ALEXANDER, Ann. & Mag. Nat. Hist. IX 13 (1924) 564–565.

Type locality: Raetihi Hill, 2,800 feet, November 20–30, 1923.

61. LIMONIA (DICRANOMYIA) SPERATA (Alexander).

Dicranomyia sperata ALEXANDER, Ann. Ent. Soc. America 15 (1922) 224–225.

A characteristic mountain species. Ruapehu, 4,000 to 4,500 feet, January 20, 1924; 4,500 feet, February 26, 1922. "Secured at night with lamp, some on rocks near water, others in flight or resting on small bushes."—*Harris.*

62. LIMONIA (DICRANOMYIA) SPONSA (Alexander).*

Dicranomyia sponsa ALEXANDER, Insec. Inscit. Menst. 10 (1922) 199–200.

Type locality: Ohakune, April 10, 1922. Ohakune, May 16, 1922.

63. LIMONIA (DICRANOMYIA) SUBFASCIATA (Alexander).*

Dicranomyia subfasciata ALEXANDER, Ann. & Mag. Nat. Hist. IX 13 (1924) 563–564.

Type locality: Raetihi Hill, 2,800 feet, November 20–30, 1923.

64. LIMONIA (DICRANOMYIA) SUBVIRIDIS (Alexander).

Dicranomyia subviridis ALEXANDER, Ann. Ent. Soc. America 15 (1922) 223–224.

One female, Ohakune, October 29, 1921.

65. LIMONIA (DICRANOMYIA) SULPHURALIS CHLOROPHYLLOIDES (Alexander).

Dicranomyia sulphuralis chlorophylloides ALEXANDER, Ann. & Mag. Nat. Hist. IX 16 (1925) 67.

Spring and early summer. Ohakune, September 21 to October 13, 1921; November 14–24 and January 24, 1922; July 17, 1923, in bush. One specimen has cell 1st M_2 open in both wings.

66. LIMONIA (DICRANOMYIA) TARSALBA (Alexander).*

Dicranomyia tarsalba ALEXANDER, Ann. & Mag. Nat. Hist. IX 9 (1922) 505–506.

Type locality: Ohakune, November 10, 1921. Ohakune, November 14–16, 1922; November 22, 1922, in a half-dry patch of swampy ground, chiefly toetoe (*Arundo conspicua* Forster f.), with a few trees and shrubs; December 13, 1922. Karioi, in beech forest, November 7, 1923. Raetihi Hill, 2,800 feet, November 20–30, 1923.

67. LIMONIA (DICRANOMYIA) TORRENS (Alexander).*

Dicranomyia torrens ALEXANDER, Ann. & Mag. Nat. Hist. IX 11 (1923) 194–195.

Type locality: Ohakune, November 18–20, 1921. "These were swarming up and down the damp face of a papa-rock cliff near a small waterfall; many were mating or attempting copulation, while others were walking about on the face of the cliff."—*Harris.*

68. LIMONIA (DICRANOMYIA) TRISTIGMATA (Alexander).*

Dicranomyia tristigmata ALEXANDER, Ann. & Mag. Nat. Hist. IX 16 (1925) 68–69.

Type locality: Karioi, in beech forest, April 14, 1924.

69. LIMONIA (DICRANOMYIA) VICARIANS (Schiner).

Limnobia vicarians SCHINER, Reise der Novara, Dipt. (1868) 46.

Occurs in the spring and fall and is presumably double brooded. Ohakune, September 26 to October 15, 1921; May 2–23 and June 13, 1923. Taihape, May 19, 1923. Karioi, in beech forest, April 14, 1924.

70. LIMONIA (DICRANOMYIA) WESCHEI (Edwards).

Dicranomyia weschei EDWARDS, Trans. N. Z. Inst. 54 (1923) 284.

A fall species appearing earlier in the season at higher altitudes. Ohakune, May 9–16 and June 13, 1923. Taihape, May 19, 1923; Ruapehu, 4,000 to 4,500 feet, January 20, 1924.

71. DISCOBOLA AMPLA (Hutton).

Trochobola ampla HUTTON, Trans. N. Z. Inst. 32 (1900) 36–37.

This striking crane fly is commonest in the spring and fall and is presumably double brooded. In the bush it persists into

the winter months. Ohakune, October 10–25, 1921; October 18 to November 26, 1922; December 23, 1921; May 7, 1922; June 13, 1923; July, 1921. Owhango, April 7, 1922; "wings folded over back, legs stretched in all directions." Ruapehu, beech zone, 3,000 to 4,000 feet, January 15, 1923; 4,500 feet, night of February 26, 1922; "hanging with a few legs on a small beech near creek."—*Harris.*

72. DISCOBOLA GIBBERA Edwards.

Discobola gibbera EDWARDS, Trans. N. Z. Inst. 54 (1923) 286.

A spring species. Ohakune, October 10–19 and November 3–28, 1921; December 2, 1922; December 23, 1921.

73. DISCOBOLA PICTA (Hutton).

Trochobola picta HUTTON, Trans. N. Z. Inst. 32 (1900) 37.

A spring species. Ohakune, October 10–27 and November 3–16, 1921; November 26, 1922. Raetihi Hill, November 30, 1923; December 14, 1922, on shrubs in bush.

74. DISCOBOLA TESSELATA Osten Sacken.

Trochobola tesselata OSTEN SACKEN, Berlin. Ent. Zeitschr. 39 (1894) 266.

This abundant species occurs almost throughout the year. Ohakune, September 19 and October 20, 1921; November 22, 1922; December 23–25, 1921; January 11–24 and April 9, 1922; May 11, 1922, " on tree-trunks at night, some bobbing up and down;" July, 1921. Karioi, in beech forest, November 7, 1923. Raetihi Hill, November 30 to December 14, 1923, beating shrubs in bush. Ruapehu 2,500 feet, February 25, 1922; beech zone, 3,000 to 4,000 feet, January 12, 1923.

75. HELIUS HARRISI (Alexander).*

Rhamphidia harrisi ALEXANDER, Ann. & Mag. Nat. Hist. IX 11 (1923) 98–99.

Type locality: Ohakune, December 1, 1921.

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76. RHAMPHOPHILA SINISTRA (Hutton).

Limnophila sinistra HUTTON, Trans. N. Z. Inst. 32 (1900) 40.

Spring and early summer. Ohakune, October 27 to November 16, 1921; October 18, November 22, December 31, and January 24, 1922; January 10, 1923. Raetihi Hill, 2,800 feet, November

20, 1923. Ruapehu, beech zone, January 15, 1923; January 20, 1924.

"These seem to vary somewhat in color. They appear to prefer the ground, although found in other situations. When at rest the legs are bent and the wings folded over the back. They invariably make short flights of a few yards and then settle but are fairly quick on the wing."—*Harris.*

77. TINEMYIA MARGARITIFERA Hutton.

Tinemyia margaritifera HUTTON, Trans. N. Z. Inst. 32 (1900) 44.

A spring species. Karioi, in beech forest, November 7, 1923. Raetihi Hill, 2,800 feet, November 20, 1923.

78. NOTHOPHILA FUSCANA (Edwards).

Ulomorpha fuscana EDWARDS, Trans. N. Z. Inst. 54 (1923) 305.

Late summer and fall. Ohakune, March 11, 1923, in bush; April 11, 1922. Karioi, in beech forest, April 14, 1924.

79. AUSTROLIMNOPHILA ARGUS (Hutton).

Limnophila argus HUTTON, Trans. N. Z. Inst. 32 (1900) 41.

Spring and early summer. Ohakune, September 19, October 25–30, and November 4–11, 1921; November 22, December 31, and January 9–24, 1922. Karioi, in beech forest, November 7, 1923. Raetihi Hill, 2,800 feet, December 14, 1922. Ruapehu, beech zone, 3,000 to 4,000 feet, January 12, 1923; 4,000 to 4,500 feet, January 20, 1924.

80. AUSTROLIMNOPHILA CHRYSORRHŒA (Edwards).

Limnophila chrysorrhœa EDWARDS, Trans. N. Z. Inst. 54 (1923) 311–312.

An early summer mountain species. Raetihi Hill, November 20–30, 1923; December 14, 1922. Ruapehu, beech zone, 3,000 to 4,000 feet, January 12, 1923; January 20, 1924.

81. AUSTROLIMNOPHILA CYATHETI (Edwards).

Limnophila cyatheti EDWARDS, Trans. N. Z. Inst. 54 (1923) 313–314.

Ohakune, March 11, 1923, in bush. Karioi, in beech forest, November 7, 1923; emerged from pupa found in decaying wood.

82. AUSTROLIMNOPHILA GEOGRAPHICA (Hutton).

Limnophila geographica HUTTON, Trans. N. Z. Inst. 32 (1900) 43–44.

Spring and early summer. Ohakune, November 18, 1921; November 1–22, December 5, and January 11, 1922. Karioi, in beech forest, November 7, 1923. Raetihi Hill, November 20–30, 1923; December 14, 1922.

83. AUSTROLIMNOPHILA HUDSONI ATRIPES (Alexander).*

Limnophila hudsoni atripes ALEXANDER, Ann. & Mag. Nat. Hist. IX 10 (1922) 92.

Late spring and early summer. Type locality: Ohakune, November 6–14, 1921. Ohakune, December 23–31, 1921; January 5, 1923. Karioi, in beech forest, November 7, 1923.

84. AUSTROLIMNOPHILA LEUCOMELAS (Edwards).

Limnophila leucomelas EDWARDS, Trans. N. Z. Inst. 54 (1923) 308.

Early summer. Ohakune, December 23, 1921; December 1–2, 1922. Raetihi Hill, December 14, 1922. Ruapehu, beech zone, January 12–15, 1923.

85. AUSTROLIMNOPHILA MARSHALLI (Hutton).

Limnophila marshalli HUTTON, Trans. N. Z. Inst. 32 (1900) 42.
Limnophila umbrosa HUTTON, Trans. N. Z. Inst. 32 (1900) 43.

Late spring and early summer. Ohakune, November 22, December 31, and January 9, 1922. Raetihi Hill, December 13–14, 1922; November 30, 1923. Ruapehu, beech zone, 3,000 to 4,000 feet, January 12, 1923.

86. AUSTROLIMNOPHILA NIGROCINCTA (Edwards).

Limnophila nigrocincta EDWARDS, Trans. N. Z. Inst. 54 (1923) 312–313.

Late spring and early summer. Ohakune, November 12, 1921; December 5–13 and January 11, 1922. Raetihi Hill, November 20–30, 1923; December 14, 1922. Ruapehu, beech zone, 3,000 to 4,000 feet, January 12, 1923.

87. AUSTROLIMNOPHILA OCULATA (Edwards).

Limnophila oculata EDWARDS, Trans. N. Z. Inst. 54 (1923) 310–311.

Early summer. Ohakune, January 11–18, 1922. Ruapehu, 4,000 feet, January 15, 1923; "a pair in copula, resting on beech trunk; legs spread out flat, wings folded over back."—*Harris.*

88. AUSTROLIMNOPHILA STEMMA (Alexander).*

Limnophila stemma ALEXANDER, Insec. Inscit. Menst. 10 (1922) 201–202.

Type locality: Ohakune, November 18, 1921. Raetihi Hill, November 20–30, 1923; December 14, 1922; "taken near a spring on damp hillside in bush."—*Harris.*

89. AUSTROLIMNOPHILA SUBINTERVENTA (Edwards).

Limnophila subinterventa EDWARDS, Trans. N. Z. Inst. 54 (1923) 309.

Early summer. Raetihi Hill, December 13, 1922. Ruapehu, beech zone, 3,000 to 4,000 feet, January 12, 1923; 4,000 feet, January 4, 1924.

90. ACANTHOLIMNOPHILA MAORICA (Alexander).*

Limnophila maorica ALEXANDER, Ann. & Mag. Nat. Hist. IX 9 (1922) 309–310.

Spring. Type locality: Ohakune, September 21 to October 11, 1921. Ohakune, October 19–20, 1921; October 22 to November 16, 1922. Karioi, in beech forest, November 7, 1923. Raetihi Hill, November 20–30, 1923.

91. HETEROLIMNOPHILA SUBTRUNCATA (Alexander).*

Limnophila subtruncata ALEXANDER, Ann. & Mag. Nat. Hist. IX 11 (1923) 199–200.

Type locality: Ohakune, January 18, 1922.

92. HETEROLIMNOPHILA TRUNCATA (Alexander).

Limnophila truncata ALEXANDER, Ann. & Mag. Nat. Hist. IX 10 (1922) 93–94.

Spring and early summer. Raetihi Hill, November 20–30, 1923. Ruapehu, beech zone, 3,000 to 4,000 feet, January 12, 1923; January 20, 1924.

93. LIMNOPHILELLA DELICATULA (Hutton).

Limnophila delicatula HUTTON, Trans. N. Z. Inst. 32 (1900) 42.

Spring and early summer. Ohakune, November 14–22 and December 1, 1922; January 5, 1923; "among ferns near creek; they seem to prefer damp places."—*Harris.* Raetihi Hill, December 14, 1922.

94. LIMNOPHILA QUÆSITA Alexander.*

Limnophila quæsita ALEXANDER, Ann. & Mag. Nat. Hist. IX 12 (1923) 109–110.

Type locality: Ohakune, November 8, 1922. Ohakune, October 30, 1923. Karioi, in beech forest, November 7, 1923.

95. METALIMNOPHILA HOWESI (Alexander).

Limnophila howesi ALEXANDER, Ann. & Mag. Nat. Hist. IX 9 (1922) 513–514.

Spring. Ohakune, November 14–22, 1922. Raetihi Hill, 2,800 feet, November 20–30, 1923.

96. METALIMNOPHILA MIRIFICA (Alexander).*

Limnophila mirifica ALEXANDER, Ann. & Mag. Nat. Hist. IX 9 (1922) 310–311.

Type locality: Ohakune, October 10, 1921. Ruapehu, beech zone, 3,000 to 4,000 feet, January 12, 1923; 4,000 to 4,500 feet, January 20, 1924.

97. METALIMNOPHILA NEMOCERA (Alexander).*

Limnophila nemocera ALEXANDER, Ann. & Mag. Nat. Hist. IX 12 (1923) 107–108.

Type locality: Ohakune, September 17, 1922.

98. METALIMNOPHILA PROTEA Alexander.*

Metalimnophila protea ALEXANDER, Ann. & Mag. Nat. Hist. IX 16 (1925) 69–71.

Type locality: Ruapehu, beech zone, 3,000 to 4,000 feet, January 20, 1924.

99. METALIMNOPHILA UNIPUNCTA (Alexander).

Limnophila unipuncta ALEXANDER, Ann. & Mag. Nat. Hist. IX 10 (1922) 94–95.

Raetihi Hill, 2,800 feet, November 20, 1923.

100. NOTHOLIMNOPHILA EXCLUSA (Alexander).*

Limnophila exclusa ALEXANDER, Ann. & Mag. Nat. Hist. IX 9 (1922) 517–518.

Type locality: Ohakune, November 12, 1921. Ohakune, December 10, 1922, beating in bush; January 4, 1922.

101. ZELANDOMYIA CINEREIPLEURA (Alexander).

Limnophila cinereipleura ALEXANDER, Ann. & Mag. Nat. Hist. IX 10 (1922) 92–93.

Late spring. Ohakune, November 22, 1922, in a half-dry swampy patch, chiefly toetoe (*Arundo conspicua* Forster f.), with a few trees and shrubs; December 1, 1922, on mint; December 5–10, 1922.

102. ZELANDOMYIA PENTHOPTERA Alexander.*

Zelandomyia penthoptera ALEXANDER, Ann. & Mag. Nat. Hist. IX 13 (1924) 371–372.

Type locality: Ohakune, March 23 to April 6, 1923. Ruapehu, 4,000 to 4,500 feet, January 20, 1924.

103. ZELANDOMYIA PYGMÆA Alexander.*

Zelandomyia pygmæa ALEXANDER, Ann. & Mag. Nat. Hist. IX 11 (1923) 106–107.

Type locality: Ohakune, January 28, 1922.

104. ZELANDOMYIA RUAPEHUENSIS (Alexander).*

Limnophila ruapehuensis ALEXANDER, Ann. & Mag. Nat. Hist. IX 9 (1922) 153–154.

Type locality: Ruapehu, 4,000 to 5,000 feet, January, 1921 (*Watt*). Ohakune, November 14–22, 1922. Ruapehu, 4,000 to 4,500 feet, January 20, 1924.

105. ZELANDOMYIA WATTI (Alexander).*

Limnophila watti ALEXANDER, Ann. & Mag. Nat. Hist. IX 9 (1922) 152–153.

Type locality: Ruapehu, 4,000 to 4,500 feet, January, 1921 (*Watt*). Ruapehu, beech zone, 3,000 to 4,000 feet, January 20, 1924.

106. GYNOPLISTIA (PARALIMNOPHILA) SKUSEI (Hutton).

Limnophila skusei HUTTON, Trans. N. Z. Inst. 34 (1902) 190–191.

Wide-spread throughout the season. Ohakune, October 11–15, 1921; October 18–31, 1922; November 16, 1921; January 10 and February 16, 1922. Taihape, May 6, 1922; "a few still about."—*Harris.* Ruapehu, beech zone, 3,000 to 4,000 feet, January 12, 1923. "This species holds on flat surfaces with all legs on support, wings folded over body, the latter tilted at an angle of from 80° to 90°."—*Harris.*

107. GYNOPLISTIA (GYNOPLISTIA) BILOBATA Alexander.*

Gynoplistia bilobata ALEXANDER, Ann. & Mag. Nat. Hist. IX 12 (1923) 205.

Type locality: Ohakune, November 16–25, 1921; December 1, 1922.

108. GYNOPLISTIA (GYNOPLISTIA) BONA Alexander.

Gynoplistia bona ALEXANDER, Insec. Inscit. Menst. 8 (1920) 123–125.

Late spring and early summer. Ohakune, December 1–31 and January 9–24, 1922; January 5–11, 1923; "rests with legs half-spread, wings folded over back."—*Harris.*

109. GYNOPLISTIA (GYNOPLISTIA) CONCAVA Alexander.*

Gynoplistia concava ALEXANDER, Ann. & Mag. Nat. Hist. IX 9 (1922) 311–312.

Spring. Type locality: Ohakune, October 3, 1921. Taihape, October 12–22, 1921. Ohakune, October 24, 1922.

110. GYNOPLISTIA (GYNOPLISTIA) ELUTA Alexander.*

Gynoplistia eluta ALEXANDER, Ann. & Mag. Nat. Hist. IX 11 (1923) 107–108.

Early summer. Type locality: Ohakune, December 20–25, 1921; Waimarino, January, 1922 (*Fenwick*). Ohakune, December 29, 1922; January 10, 1923.

111. GYNOPLISTIA (GYNOPLISTIA) FIMBRIATA Alexander.

Gynoplistia fimbriata ALEXANDER, Insec. Inscit. Menst. 8 (1920) 126–128.

Late spring and early summer. Ohakune, November 16, 1921; December 9, 1922. Ruapehu, beech zone, 3,000 to 4,000 feet, January 20, 1924.

112. GYNOPLISTIA (GYNOPLISTIA) FUSCOPLUMEA Edwards.

Gynoplistia fuscoplumbea EDWARDS, Trans. N. Z. Inst. 54 (1923) 318.

Late spring. Ohakune, November 18, 1921; December 1 and 2, 1922.

113. GYNOPLISTIA (GYNOPLISTIA) GLAUCA Edwards.

Gynoplistia glauca EDWARDS, Trans. N. Z. Inst. 54 (1923) 318.

Early summer. Ohakune, December 10 and January 4, 1922; January 15, 1923.

114. GYNOPLISTIA (GYNOPLISTIA) HARRISI Alexander.*

Gynoplistia harrisi ALEXANDER, Ann. Ent. Soc. America 15 (1922) 231–232.

Type locality: Ohakune, February, 1920.

115. GYNOPLISTIA (GYNOPLISTIA) HIEMALIS (Alexander).*

Cerozodia hiemalis ALEXANDER, Ann. & Mag. Nat. Hist. IX 11 (1923) 108.

Gynoplistia hiemalis ALEXANDER, Ann. & Mag. Nat. Hist. IX 13 (1924) 372.

Winter. Type locality: Ohakune, July, 1921, in bush. The unique type, a female, was found hanging near the bottom of a small shrub near the ground. It was found in the daytime and was the only specimen observed. On June 14, 1923, Harris found five additional females. One of these was resting against a tree trunk, the beautiful male nearby, hanging to a small shrub by a couple of legs. These were taken at night; the male and a female were placed in a box and kept alive for a time to see if they would mate. Although very sluggish in the bush, the nearly apterous females became very lively in the observation boxes, but no mating occurred. On June 22, 1923, Harris found a second male. This was resting on a tree trunk, stowed away amongst some vines, the wings folded incumbent over the back, the legs spread apart. At about the same time, Dr. John G. Myers secured two additional males in the Wainui State Forest, Wellington. One of these was beaten from a dead tawa tree that had been recently felled, the second from the dead, hanging fronds of a tree fern (either *Hemitelia* or *Dicksonia squarrosa*).

116. GYNOPLISTIA (GYNOPLISTIA) INCISA Edwards.

Gynoplistia incisa EDWARDS, Trans. N. Z. Inst. 54 (1923) 318–319.

Ohakune, December 25, 1921.

117. GYNOPLISTIA (GYNOPLISTIA) LOBULIFERA Alexander.*

Gynoplistia lobulifera ALEXANDER, Ann. & Mag. Nat. Hist. IX 12 (1923) 209–210.

Type locality: Ohakune to the mountain hut on Ruapehu, beech zone, 3,000 to 4,500 feet, January 12–15, 1923.

118. GYNOPLISTIA (GYNOPLISTIA) LUTEICINCTA Alexander.*

Gynoplistia luteicincta ALEXANDER, Ann. & Mag. Nat. Hist. IX 13 (1924) 576–577.

Type locality: Ohakune, December 12, 1922. Karioi, in beech forest, November 7, 1923.

119. GYNOPLISTIA (GYNOPLISTIA) NIVEICINCTA Alexander.*

Gynoplistia niveicincta ALEXANDER, Ann. & Mag. Nat. Hist. IX 9 (1922) 519–520.

Type locality: Ohakune, December 15, 1919.

120. GYNOPLISTIA (GYNOPLISTIA) OCELLIFERA Alexander.*

Gynoplistia ocellifera ALEXANDER, Ann. & Mag. Nat Hist. IX 12 (1923) 111–112.

Type locality: Raurimu, June 7, 1922.

121. GYNOPLISTIA (GYNOPLISTIA) OROPHILA Edwards.*

Gynoplistia orophila EDWARDS, Ann. & Mag. Nat. Hist. IX 11 (1923) 628–629.

Type locality: Whakapapa, Ruapehu, altitude 4,000 feet, January, 1922 (*Hudson*).

122. GYNOPLISTIA (GYNOPLISTIA) PLEURALIS Alexander.*

Gynoplistia pleuralis ALEXANDER, Ann. & Mag. Nat. Hist. IX 12 (1923) 208–209.

Type locality: Ohakune to the mountain hut on Ruapehu, beech zone, 3,000 to 4,500 feet, January 12–15, 1923.

123. GYNOPLISTIA (GYNOPLISTIA) RECURVATA Alexander.*

Gynoplistia recurvata ALEXANDER, Ann. & Mag. Nat. Hist. IX 12 (1923) 211–212.

Type locality: Ohakune, December 1–12, 1922, on mint.

124. GYNOPLISTIA (GYNOPLISTIA) SACKENI Alexander.

Gynoplistia sackeni ALEXANDER, Insec. Inscit. Menst. 8 (1920) 125–126.

Spring. Ohakune, September 29–30 and October 1–4, 1921. Karioi, in beech forest, November 7, 1923. Raetihi Hill, November 20–30, 1923.

125. GYNOPLISTIA (GYNOPLISTIA) SPINICALCAR Alexander.*

Gynoplistia spinicalcar ALEXANDER, Ann. Ent. Soc. America 15 (1922) 230–231.

Type locality: Ohakune, March 1, 1919.

126. GYNOPLISTIA (GYNOPLISTIA) SPLENDENS Alexander.*

Gynoplistia splendens ALEXANDER, Ann. Ent. Soc. America 15 (1922) 233–234.

Type locality: Ohakune, February 15, 1920.

127. GYNOPLISTIA (GYNOPLISTIA) SUBCLAVIPES Alexander.*

Gynoplistia subclavipes ALEXANDER, Ann. & Mag. Nat. Hist. IX 13 (1924) 373–375.

Type locality: Ohakune, December 17, 1922.

128. GYNOPLISTIA (GYNOPLISTIA) SUBFASCIATA Walker.

Gynoplistia subfasciata WALKER, List. Dipt. Brit. Mus. 1 (1848) 74.

Spring. Ohakune, November 16 and December 1, 1921.

129. GYNOPLISTIA (GYNOPLISTIA) TRIDACTYLA Edwards.

Gynoplistia tridactyla EDWARDS, Trans. N. Z. Inst. 54 (1923) 321.

Spring and fall. Ohakune, October 22, 1922; April 20, 1923.

130. GYNOULISTIA (CEROZODIA) HUDSONI HEMIPTERA (Alexander).*

Cerozodia hudsoni hemiptera ALEXANDER, Insec. Inscit. Menst. 10 (1922) 203–204.

Type locality: Ruapehu, 4,000 to 5,000 feet, January, 1921 (*Watt*). Ohakune, January 11, 1922. Ruapehu, beech zone, 3,000 to 4,000 feet, January 12, 1923.

131. ISCHNOTHRIX CONNEXA (Alexander).*

Orolimnophila connexa ALEXANDER, Ann. & Mag. Nat. Hist. IX 11 (1923) 198–199.

Type locality: Ohakune, July, 1921. Ohakune, May 2, 1923. Horopito, 2,300 feet, February, 1922; "on uprights of water tank on wet morning."—*Harris*. Ruapehu, beech zone, 3,000 to 4,000 feet, February 26, 1922; 4,000 to 4,500 feet, January 20, 1924.

132. ATARBA (ATARBA) FILICORNIS Alexander.

Atarba filicornis ALEXANDER, Ann. & Mag. Nat. Hist. IX 9 (1922) 151–152.

Spring and early summer. Ohakune, November 8–26 and December 1, 1922; December 25, 1921; January 18, 1922. Raetihi Hill, 2,800 feet, November 20–30, 1923; December 14, 1922. Ruapehu, beech zone, 3,000 to 4,000 feet, January 12, 1923; 4,000 feet, January 4, 1924.

133. ATARBA (ATARBA) VIRIDICOLOR Alexander.*

Atarba viridicolor ALEXANDER, Ann. & Mag. Nat. Hist. IX 9 (1922) 308.

Spring. Type locality: Ohakune, October 11, 1921. Ohakune, November 3, 1921; November 24–26, 1922. Karioi, in beech

forest, November 7, 1923. Raetihi Hill, 2,800 feet, November 20–30, 1923.

134. ELEPHANTOMYIA RUAPEHUENSIS Alexander.*

Elephantomyia ruapehuensis ALEXANDER, Ann. & Mag. Nat. Hist. IX 12 (1923) 204–205.

Type locality: Ruapehu, beech zone, 3,000 to 4,000 feet, January 15, 1923. A second specimen, a male, was taken near the type locality, January 4, 1924, at an altitude of 4,000 feet.

135. ELEPHANTOMYIA ZEALANDICA Edwards.

Elephantomyia zealandica EDWARDS, Trans. N. Z. Inst. 54 (1923) 288.

Ohakune, December 7, 1923. Ruapehu, beech zone, 3,000 to 4,000 feet, January 20, 1924; 4,000 to 4,500 feet, January 20, 1924.

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136. CERATOCHEILUS LEVIS (Hutton).

Rhamphidia levis HUTTON, Trans. N. Z. Inst. 32 (1900) 38.

Ohakune, December 17, 1922; December 7, 1923.

137. CERATOCHEILUS OCHRACEUM Edwards.

Ceratocheilus ochraceum EDWARDS, Trans. N. Z. Inst. 54 (1923) 289.

Ruapehu, 4,000 to 5,000 feet, January, 1921 (*Watt*).

138. RHABDOMASTIX (SACANDAGA) OPTATA Alexander.*

Rhabdomastix optata ALEXANDER, Ann. & Mag. Nat. Hist. IX 11 (1923) 104–105.

Type locality: Ohakune, January 24 to February 8, 1922.

139. RHABDOMASTIX (SACANDAGA) TRICHIATA Alexander.*

Rhabdomastix trichiata ALEXANDER, Ann. & Mag. Nat. Hist. IX 11 (1923) 197–198.

Type locality: Ohakune, February 8, 1922. Ohakune, December 2, 1922.

140. RHABDOMASTIX (SACANDAGA) VITTITHORAX Alexander.*

Rhabdomastix vittithorax ALEXANDER, Ann. & Mag. Nat. Hist. IX 11 (1923) 105–106.

Type locality: Ohakune, January 28, 1922.

141. GONOMYIA (LIPOPHLEPS) LONGISPINA Alexander.*

Gonomyia longispina ALEXANDER, Insec. Inscit. Menst. 10 (1922) 201.

Type locality: Ohakune, April 9, 1922.

142. GONOMYIA (LIPOPHLEPS) NIGROHALTERATA Edwards.

Gonomyia nigrohalterata EDWARDS, Trans. N. Z. Inst. 54 (1923) 290.

Spring and early summer. Ohakune, November 24 and December 2, 1922. Taihape, October 14, 1921. Raetihi Hill, near base, December 13, 1922.

143. CAMPBELLOMYIA ALPINA ALPINA (Alexander).

Gnophomyia (?) *alpina* ALEXANDER, Ann. & Mag. Nat. Hist. IX 10 (1922) 565–566.

Ohakune, February 24, 1922.

143a. CAMPBELLOMYIA ALPINA FULVIPLEURA (Alexander).*

Gnophomyia alpina fulvipleura ALEXANDER, Ann. & Mag. Nat. Hist. IX 12 (1923) 203–204.

Type locality: Ohakune, December 1, 1922.

143b. CAMPBELLOMYIA ALPINA FUMIPENNIS (Alexander).*

Gnophomyia alpina fumipennis ALEXANDER, Ann. & Mag. Nat. Hist. IX 12 (1923) 203.

Type locality: Ohakune, December 13, 1922.

144. APHROPHILA FLAVOPYGIALIS (Alexander).

Gnophomyia flavopygialis ALEXANDER, Ann. & Mag. Nat. Hist. IX 9 (1922) 150–151.

Summer. Ohakune, November 16 and December 25, 1921; December 1–29, 1922; January 28, 1921; February 1–5, 1922. Ruapehu, 4,000 feet, January 4, 1924.

145. APHROPHILA NEOZELANDICA (Edwards).

Gnophomyia (*Aphrophila*) *neozelandica* EDWARDS, Trans. N. Z. Inst. 54 (1923) 298.

Ohakune, February 8, 1922. Popaka, February, 1922. Ruapehu, 4,500 feet, February 26, 1922. "These skim along the surface of the water like a hydroplane. When resting, they settle on wet rocks, usually on the underside of an inclined bowlder. Mating takes place in similar situations."—*Harris.*

146. TRIMICRA INCONSTANS Alexander.

Trimicra inconstans ALEXANDER, Ann. & Mag. Nat. Hist. IX 9 (1922) 148–149.

Ohakune, November 1–16, 1921; February 8, 1922; April 4, 1923. Taihape, October 22, 1921. Karioi, in beech forest, November 7, 1923.

147. TASIOCERA PAULULA (Alexander).*

Molophilus paululus ALEXANDER, Ann. & Mag. Nat. Hist. IX 11 (1923) 103–104.

Type locality: Ohakune, January 18, 1922.

148. MOLOPHILUS AUCKLANDICUS Alexander.*

Molophilus aucklandicus ALEXANDER, Ann. & Mag. Nat. Hist. IX 12 (1923) 106–107.

Type locality: Ruapehu, beech zone, 3,000 to 4,000 feet, February 26, 1922; 4,500 feet, February 27, 1922.

149. MOLOPHILUS BIDENS Alexander.*

Molophilus bidens ALEXANDER, Ann. & Mag. Nat. Hist. IX 12 (1923) 202.

Type locality: Ohakune, December 10, 1922. Ruapehu, beech zone, 3,000 to 4,000 feet, January 12, 1923.

150. MOLOPHILUS BREVINERVIS Alexander.*

Molophilus brevinervis ALEXANDER, Ann. & Mag. Nat. Hist. IX 11 (1923) 102–103.

Type locality: Ohakune, December 22, 1921.

151. MOLOPHILUS CRUCIFERUS Alexander.

Molophilus cruciferus ALEXANDER, Ann. & Mag. Nat. Hist. IX 9 (1922) 147.

Ohakune, December 1, 1922.

152. MOLOPHILUS FLAGELLIFER Alexander.*

Molophilus flagellifer ALEXANDER, Ann. & Mag. Nat. Hist. IX 10 (1922) 560.

A characteristic mountain species. Type locality: Ruapehu, 3,700 feet, January 6, 1922 (*Watt*). Ohakune, November 14–24, 1922. Karioi, in beech forest, November 7, 1923. Raetihi Hill, 2,800 feet, November 20, 1923. Ruapehu, beech zone, January 12, 1923; February 26, 1922; 4,000 to 4,500 feet, January 4–20, 1924.

153. MOLOPHILUS FLAVIDULUS Alexander.*

Molophilus flavidulus ALEXANDER, Ann. & Mag. Nat. Hist. IX 11 (1923) 100.

Type locality: Ohakune, January 18, 1922. Ohakune, May 10, 1923. Karioi, in beech forest, November 7, 1923.

154. MOLOPHILUS FLAVOMARGINALIS Alexander.*

Molophilus flavomarginalis ALEXANDER, Ann. & Mag. Nat. Hist. IX 12 (1923) 105–106.

Type locality: Ohakune, November 14, 1922.

155. MOLOPHILUS HARRISIANUS Alexander.*

Molophilus harrisianus ALEXANDER, Ann. & Mag. Nat. Hist. IX 15 (1925) 649–650.

Type locality: Ruapehu, 4,000 to 4,500 feet, January 20, 1924.

156. MOLOPHILUS HEXACANTHUS Alexander.*

Molophilus hexacanthus ALEXANDER, Ann. & Mag. Nat. Hist. IX 13 (1924) 567.

Type locality: Raetihi Hill, 2,800 feet, November 20, 1923.

157. MOLOPHILUS HILARIS Alexander.*

Molophilus hilaris ALEXANDER, Ann. & Mag. Nat. Hist. IX 11 (1923) 99–100.

Type locality: Ohakune, January 24, 1922. Ohakune, December 1, 1922.

158. MOLOPHILUS HOWESI Alexander.

Molophilus howesi ALEXANDER, Ann. & Mag. Nat. Hist. IX 11 (1923) 195–196.

Spring. Ohakune, November 14–24, 1922. Karioi, in beech forest, November 7, 1923.

159. MOLOPHILUS IRREGULARIS Alexander.*

Molophilus irregularis ALEXANDER, Ann. & Mag. Nat. Hist. IX 11 (1923) 196–197.

A characteristic mountain species. Type locality: Ruapehu, 4,500 feet. February 27, 1922. Ohakune, November 14–16 and December 1–17, 1922. Ruapehu, beech zone, 3,000 to 4,000 feet, January 12, 1923; 4,000 to 4,500 feet, January 4–20, 1924.

160. MOLOPHILUS LATIPENNIS Alexander.*

Molophilus latipennis ALEXANDER, Ann. & Mag. Nat. Hist. IX 12 (1923) 198–199.

A characteristic mountain species. Type locality: Ruapehu, beech zone, 3,000 to 4,000 feet, January 12, 1923. Ruapehu, 4,000 to 4,500 feet, January 20, 1924.

161. MOLOPHILUS LUTEIPYGUS Alexander.*

Molophilus luteipygus ALEXANDER, Ann. & Mag. Nat. Hist. IX 9 (1922) 510–511.

Karioi, in beech forest, April 14, 1924.

162. MOLOPHILUS MACROCERUS Alexander.*

Molophilus macrocerus ALEXANDER, Ann. & Mag. Nat. Hist. IX 9 (1922) 297–298.

Winter and early spring. Type locality: Ohakune, September 14 to October 15, 1921. Ohakune, June 13, 1923; July, 1921; July 11, 1923.

163. MOLOPHILUS MOROSUS Alexander.

Molophilus morosus ALEXANDER, Ann. & Mag. Nat. Hist. IX 12 (1923) 104–105.

Ruapehu, 4,000 to 4,500 feet, January 20, 1924.

164. MOLOPHILUS MULTICINCTUS Edwards.

Molophilus multicinctus EDWARDS, Trans. N. Z. Inst. 54 (1923) 295.

Spring, fall, and early summer; presumably double brooded. Ohakune, September 23, 1921; October 10–31, 1921; November

12, 1922, on mint; November 14–30, December 2–17, and January 18–28, 1922; February 24, 1922, "about fifty or sixty of these were swarming over a damp patch, close to ground."—*Harris;* May 2–16, 1923. Karioi, in beech forest, November 7, 1923.

165. MOLOPHILUS NIVEICINCTUS Alexander.*

Molophilus niveicinctus ALEXANDER, Ann. & Mag. Nat. Hist. IX 10 (1922) 560–561.

Type locality: Ruapehu, 3,700 feet, January 6, 1922 (*Watt*).

166. MOLOPHILUS OHAKUNENSIS Alexander.*

Molophilus quadrifidus ohakunensis ALEXANDER, Ann. & Mag. Nat. Hist. IX 11 (1923) 102.

Type locality: Ohakune, February 9 to March 10, 1922. Ohakune, November 30, 1922.

167. MOLOPHILUS OPPOSITUS Alexander.*

Molophilus oppositus ALEXANDER, Ann. & Mag. Nat. Hist. IX 12 (1923) 201.

Type locality: Ruapehu, beech zone, 3,000 to 4,000 feet, January 12, 1923.

168. MOLOPHILUS PARVULUS Alexander.*

Molophilus parvulus ALEXANDER, Ann. & Mag. Nat. Hist. IX 9 (1922) 146.

Type locality: Ohakune, November 10, 1920.

169. MOLOPHILUS PHILPOTTI Alexander.

Molophilus philpotti ALEXANDER, Ann. & Mag. Nat. Hist. IX 9 (1922) 145–146.

Ruapehu, 3,700 feet, January 6, 1922 (*Watt*).

170. MOLOPHILUS PLAGIATUS Alexander.*

Molophilus plagiatus ALEXANDER, Ann. & Mag. Nat. Hist. IX 9 (1922) 301–302.

Spring, recurring in the fall; probably double brooded. Type locality: Ohakune, October 7–27, 1921. Ohakune, October 27, November 12–22, and December 23, 1922; April 4, 1923. Karioi, in beech forest, November 7, 1923.

171. MOLOPHILUS PULCHERRIMUS Edwards.

Molophilus pulcherrimus EDWARDS, Trans. N. Z. Inst. 54 (1923) 295.

Summer. Ohakune, December 17–31, 1922; December 7, 1923. Ruapehu, beech zone, 3,000 to 4,000 feet, January 15, 1923; February 27, 1922; 4,000 to 4,500 feet, January 20, 1924; February 26, 1922.

172 MOLOPHILUS REPANDUS Alexander.*

Molophilus repandus ALEXANDER, Ann. & Mag. Nat. Hist. IX 12 (1923) 103–104.

Type locality: Ohakune, November 14–16, 1922.

173. MOLOPHILUS SECUNDUS Alexander.*

Molophilus secundus ALEXANDER, Ann. & Mag. Nat. Hist. IX 12 (1923) 200.

Type locality: Ohakune, December 13, 1922.

174. MOLOPHILUS SEPOSITUS Alexander.*

Molophilus sepositus ALEXANDER, Ann. & Mag. Nat. Hist. IX 11 (1923) 103.

Type locality: Ohakune, December 22, 1921.

175. MOLOPHILUS SUBLATERALIS Alexander.*

Molophilus sublateralis ALEXANDER, Ann. & Mag. Nat. Hist. IX 9 (1922) 302–303.

Type locality: Ohakune, October 7–15, 1921. Ohakune, November 14, 1922. Karioi, in beech forest, November 7, 1923.

176. MOLOPHILUS SYLVICOLUS Alexander.*

Molophilus sylvicolus ALEXANDER, Ann. & Mag. Nat. Hist. IX 13 (1924) 567–568.

Type locality: Karioi, in beech forest, November 7, 1923.

177. MOLOPHILUS TANYPUS Alexander.*

Molophilus tanypus ALEXANDER, Ann. & Mag. Nat. Hist. IX 9 (1922) 298–299.

Spring. Type locality: Ohakune, September 23, 1921.

177a. MOLOPHILUS TANYPUS COLORATUS Alexander.*

Molophilus tanypus coloratus ALEXANDER, Ann. & Mag. Nat. Hist. IX 11 (1923) 197.

Winter. Type locality: Ohakune, July, 1921.

178. MOLOPHILUS TENUISSIMUS Alexander.*

Molophilus tenuissimus ALEXANDER, Ann. & Mag. Nat. Hist. IX 12 (1923) 202–203.

Type locality: Ohakune, December 13, 1922.

179. MOLOPHILUS TENUISTYLUS Alexander.*

Molophilus tenuistylus ALEXANDER, Ann. & Mag. Nat. Hist. IX 12 (1923) 104.

Type locality: Ohakune, November 14–22, 1922. Ohakune, January 5, 1923. Raetihi Hill, 2,800 feet, November 30, 1923.

180. MOLOPHILUS TERMINANS Alexander.*

Molophilus terminans ALEXANDER, Ann. & Mag. Nat. Hist. IX 9 (1922) 511–512.

Type locality: Ohakune, November 6–15, 1921. Ohakune, November 24 and December 10, 1922; January 5, 1923; "found

near a culvert over a small creek. When at rest, legs spread out, wings folded over back."—*Harris.*

181. MOLOPHILUS UNIPLAGIATUS Alexander.*

Molophilus uniplagiatus ALEXANDER, Ann. & Mag. Nat. Hist. IX 12 (1923) 199–200.

A characteristic mountain species. Type locality: Ruapehu, beech forest, 3,000 to 4,000 feet, December 31, 1922, to January 12–15, 1923. In same locality, January 21, 1923. Ruapehu, 4,000 to 4,500 feet, January 20, 1923.

182. AMPHINEURUS (AMPHINEURUS) HUDSONI Edwards.

Amphineurus hudsoni EDWARDS, Trans. N. Z. Inst. 54 (1923) 293.

Late spring and summer. Ohakune, November 22, 1922, in a half-dry swampy toetoe patch, with some trees and shrubs; February 20, 1922. Karioi, in beech forest, November 7, 1923. Raetihi Hill, 2,800 feet, November 20–30, 1923. Ruapehu, beech zone, January 12, 1923; January 4, 1924.

183. AMPHINEURUS (AMPHINEURUS) LYRIFORMIS Alexander.*

Amphineurus lyriformis ALEXANDER, Ann. & Mag. Nat. Hist. IX 12 (1923) 101.

Type locality: Ohakune, December 1, 1922. Ruapehu, beech zone, 3,000 to 4,000 feet, January 12, 1923; 4,000 to 4,500 feet, January 4–20, 1924.

184. AMPHINEURUS (AMPHINEURUS) SENEX Alexander.

Amphineurus senex ALEXANDER, Ann. Ent. Soc. America 15 (1922) 225–226.

Ohakune, November 22, 1922, in a half-dry toetoe patch, with a few trees and shrubs. Ruapehu, beech zone, 3,000 to 4,000 feet, January 12, 1923; 4,000 to 4,500 feet, January 4–20, 1924.

185. AMPHINEURUS (NESORMOSIA) FATUUS (Hutton).

Rhypholophus fatuus HUTTON, Trans. N. Z. Inst. 34 (1900) 188.

Spring and early summer, recurring in the fall. Ohakune, November 22 and December 1–13, 1922; January 5, 1923. Raetihi Hill, 2,800 feet, April 8, 1924. Ruapehu, beech zone, 3,000 to 4,000 feet, January 12–15, 1923; 4,000 to 4,500 feet, January 20, 1924.

186. AMPHINEURUS (NESORMOSIA) SUBFATUUS Alexander.*

Amphineurus subfatuus ALEXANDER, Ann. & Mag. Nat. Hist. IX 10 (1922) 87–88.

Spring and summer, possibly double brooded. Type locality: Ohakune, November 13, 1921, to February 20, 1922. Ohakune, November 14–22, 1922, the latter in a half-dry swampy patch, chiefly of toetoe (*Arundo conspicua* Forster f.), with a few trees and shrubs; December 13, 1922; February 20, 1923.

187. AMPHINEURUS (NOTHORMOSIA) FIMBRIATULUS Alexander.

Amphineurus (*Nothormosia*) *fimbriatulus* ALEXANDER, Ann. & Mag. Nat. Hist. IX 16 (1925) 75–76.

A paratype, Ohakune, March 8, 1923 (*Tonnoir*).

188. AMPHINEURUS (NOTHORMOSIA) GRACILISENTIS Alexander.*

Amphineurus gracilisentis ALEXANDER, Ann. & Mag. Nat. Hist. IX 10 (1922) 563.

Type locality: Ruapehu, 3,700 feet, January 6, 1922 (*Watt*); Ohakune, July, 1921. Common in the spring and fall, lingering into the winter months in the bush and into the summer in the mountains. Ohakune, November 14–18, 1921; December 1–13, 1922; May 6–17 and June 13, 1923; July 11–17, 1923, in bush. Karioi, in beech forest, November 7, 1923; April 14, 1924. Raetihi Hill, 2,800 feet, November 30, 1923; April 8, 1924. Ruapehu, beech zone, 3,000 to 4,000 feet, January 12, 1923; February 26, 1922.

189. AMPHINEURUS (NOTHORMOSIA) HARRISI Alexander.*

Amphineurus harrisi ALEXANDER, Ann. & Mag. Nat. Hist. IX 9 (1922) 304–305.

Type locality: Ohakune, October 10, 1921. Ohakune, November 8–24, 1922; May 10 and July 17, 1923. Karioi, in beech forest, November 7, 1923; April 14, 1924. Raetihi Hill, 2,800 feet, November 20–30, 1923. Ruapehu, beech zone, 3,000 to 4,000 feet, February 26, 1922; 4,000 to 4,500 feet, January 20, 1924.

190. AMPHINEURUS (NOTHORMOSIA) INSULSUS (Hutton).

Rhypholophus insulsus HUTTON, Trans. N. Z. Inst. 34 (1900) 188.

Spring and fall, in the mountains persisting into the summer; probably double brooded. Ohakune, October 1–27 and November 3–28, 1921; December 2, 1922; December 13–23, 1921; May 10, 1923. Karioi, in beech forest, November 7, 1923; April 14, 1924. Raetihi Hill, 2,800 feet, November 20–30, 1923; April 8, 1924. Ruapehu, beech zone, 3,000 to 4,000 feet, January 12, 1923.

191. AMPHINEURUS (NOTHORMOSIA) NOTHOFAGI Alexander.*

Amphineurus nothofagi ALEXANDER, Ann. & Mag. Nat. Hist. IX 16 (1925) 76.

Type locality: Karioi, in beech forest, April 14, 1924.

192. AMPHINEURUS (NOTHORMOSIA) PATRUELIS Alexander.*

Amphineurus (*Nothormosia*) *patruelis* ALEXANDER, Ann. & Mag. Nat. Hist. IX 16 (1925) 78.

Ohakune, October 10–15, 1921; November 8–14 and December 4, 1922.

ILLUSTRATION

TEXT FIG. 1. Sketch map indicating the limits of Ohakune district and Tongariro Park, North Island, New Zealand (1908).

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SEX STUDIES ON PHILIPPINE FROGS AND TOADS, I

MALE INTERSEXUALITY IN RANA VITTIGERA WIEGMANN [1]

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TWO PLATES

Intersexuality in the frogs, toads, and salamanders has been the subject of numerous researches, the most comprehensive of which are those of Witchi (1921) and Crew (1921). By arranging sex abnormalities in frogs and toads as reported by various investigators in such a way that the first case in the list is that approximating a normal female and the last approaching a typical male, Crew (1921) concludes that an individual which at one time possesses characteristics of a female may transform into an individual with male sex equipment. This conclusion was supported by a completely transformed individual, formerly a female, which functioned as a male and fertilized the eggs of a normal female. All offspring of this mating that developed far enough to allow sex identification were females. Similarly striking observations were reported by Guyenot and Ponse (1923) on toads. Testes transplanted autoplastically or homoplastically, subcutaneously or intraperitoneally, into castrated males, transform, after a retention of eight to twelve months, into an ovotestis with a predominance of oögenesis. The toads, however, retained their normal male secondary sex characters. Champy (1921) found that intensively fed male tritons began to show external characters of the female. One of these, whose previous history as a male was known, when finally killed was found to have its testes replaced by an immature ovary containing young oöcytes.

Abnormal sexuality is a rather frequent occurrence among Philippine frogs, a fact well known to persons who have to obtain frog material for laboratory work. This paper describes

[1] This investigation has been aided by a grant from the Committee on Sex Research of the National Research Council of America. The grant has been obtained through the kindness of Prof. F. R. Lillie to whom the writer makes grateful acknowledgment for his constant interest in the work.

the commonest sex abnormality and attempts to explain its probable significance. The material used is the common frog, *Rana vittigera* Wiegmann, obtained from the grassy regions on the south shore of Laguna de Bay, Luzon. The other source of frogs used in our laboratory is Tinajeros, a village about 8 kilometers north of Manila. Since no sexual abnormalities are encountered among animals from the latter place and since the greater percentage of those collected from the former place show sexual irregularity in one way or another, it is thought that there may be a regional or racial difference in the sex constitution of these frogs.

For this work, all frogs from a single catch showing external characters of maleness are separated from the animals showing external features of femaleness, and a count for sex-ratio is made. Externally male-looking individuals are dissected and the condition of the gonads and reproductive ducts recorded. Frogs showing any form of abnormality are preserved for further examination after the gonads are removed and fixed. Material is fixed in Bouin's fluid, sectioned, and then stained in either Mallory's triple stain, Delafield's hæmatoxylin or Heidenhein's iron alum hæmatoxylin.

OBSERVATIONS

This paper deals with one hundred ninety-one frogs exhibiting abnormal gonads. These all possess external characters of the male; namely, pigmented sides of the throat, swollen thumbs, and vocal sacs. They are small and measure 55 millimeters from the tip of the snout to the vent on the average, as against 85 millimeters, the average length of mature females. The majority of the gonads are testislike in shape; but some are slightly flattened and broad while others, instead of being smooth and cylindrical, are lobulated or slightly inflated. In all cases, however, the gonad approaches the external appearance of a testis more than that of an ovary. Unlike normal testes, they show externally masses of pigmented spots in many regions. In all of them, the Wolffian ducts are typically male and have slight enlargements just before joining the cloaca in the form of a seminal vesicle. The Müllerian ducts, on the other hand, are larger than the ordinary vestigial oviduct of the male. Although convoluted, they do not attain the size of the oviducts of the normal female. It may be said that the Müllerian ducts of these intersexual males are half-way between those of normal males

and normal females. It has not been ascertained whether they have openings into the cloaca and from the cœlom or not.

Histologic examination shows the gonads to be ovotestes in which the testicular and the ovarian portions are not delimited from each other. The great majority of the seminiferous tubules are in active spermatogenesis, and they exhibit all stages of multiplication, maturation, and spermiogenesis. Mature spermatozoa are invariably present. The tubules are in close juxtaposition with each other, so that in the majority of cases the intertubular regions are either narrow or wanting. The interstices include for the most part ordinary connective-tissue cells, leucocytes, and pigmented cells. The last two named elements are rarely, if ever, encountered in normal frog testes.

Oögonia of different sizes are found in groups of various number, many of which, without any question, are located inside the seminiferous tubules. These oögonia-containing tubules can be divided conveniently into the following types, as seen in sections: (1) Tubules containing developing male germ cells for the most part with an admixture of few small oögonia which are attached to the walls of the seminiferous tubules. These oögonia are five to fifteen times as large as the spermatogonia and can be easily distinguished by their large and prominent germinal vesicles. They are, without any question, within the seminiferous tubules. (2) Tubules containing oögonia of medium size, free in the lumen or still attached to the tubular wall, in addition to male germ elements undergoing multiplication, maturation, and spermiogenesis. (3) Tubules containing large oögonia and a few or many mature spermatozoa. (4) Tubules containing nothing but oögonia of large size. After the oögonia have attained a large size, only two or three are encountered in a tubular section exerting a certain amount of pressure on each other such that they depart from the usual spherical shape. At this stage, also, it is often hard to figure out whether they are within or outside the seminiferous tubules.

DESCRIPTION OF A FEW CASES

Case 113.—Animal small, length from tip of snout to vent 56 millimeters; thumbs large but not much swollen; sides of throat darkly pigmented as in typical male. The gonads externally are symmetrical, oblong, narrow, 7 millimeters long and 1.2 millimeters wide. They show pigmented spots all over the surface, vasa efferentia present, seminal vesicles prominent; Mülle-

rian ducts small but slightly convoluted, joining the seminal vesicle before this enters the cloaca.

Histologic examination shows the gonads to be ovotestes in which the testicular portion is greater than the ovarian. The seminal tubules are in active spermatogenesis, showing all stages of multiplication, growth, maturation, and spermiogenesis. A few ova are large, but the greatest number are small. These are very young ova, many of which are attached to the walls of the seminiferous tubules (Plate 1, fig. 1). These ova are in no way different from young ova of a normal ovary, and they can easily be distinguished from the spermatogonia by their much larger size, by the greater amount of cytoplasmic materials, and by the large germinal vesicle. When a seminal tubule incloses these ova, both the female and the male germ elements appear normal and healthy.

Case 126.—Animal small, measuring 59 millimeters from the vent to the tip of the snout. External secondary sex characters are those of a typical male; the thumbs are swollen, the sides of the throat are pigmented, and vocal sacs are present. The gonads, externally, are alike and in no way different from normal testes except for the presence of a few pigment spots scattered on the surface. Vasa efferentia are present, and the ureters are enlarged before joining the cloaca to form a seminal vesicle. The Müllerian ducts approach the typical threadlike appearance of a male vestigial oviduct, although they show slight sinuosity.

Microscopic study of the gonads shows that they are ovotestes. The greatest part of each gonad is testicular, composed of closely set seminiferous tubules with hardly any intertubular region between them. Male germ elements are in processes of multiplication, maturation, and spermiogenesis, although mature spermatozoa may be absent in some tubular sections.

In these gonads there are only a few ova which are located near the hilum, at the center and on the surface of the gonad. By far the greatest number of these are young and small, found inside, and oftentimes attached to the walls, of seminiferous tubules (Plate 1, fig. 2). These have large clear germinal vesicles with one or several deeply staining nucleoli. The germinal vesicle is too large for the amount of cytoplasm. In these gonads the pigment cells are confined in certain basement membranes of the tubules. No pigment cells and no leucocytes are encountered around the ova.

Case 331.—Animal small; length from tip of snout to vent only 50 millimeters; thumbs swollen, typically malelike; sides of throat heavily pigmented, typical of a male in the breeding season. Gonads symmetrical, testislike externally, cylindrical, 10 millimeters long and 2 millimeters wide, with dark spots all around; vas efferens normal; seminal vesicle expanded; Müllerian ducts small, although convoluted and larger than those of a normal male, with a somewhat expanded posterior portion.

Longitudinal sections show the gonads to be ovotestes, in which the ovarian is greater than the testicular portion. There is no line of demarcation between the testicular and the ovarian portion. The testicular part includes seminiferous tubules with germ cells in all stages of spermatogenesis. The ovarian portion consists of ova of all sizes scattered throughout the gonad. Most of these are large and apparently in good health. Although these may be invested with a layer of pigment cells, they show no sign of degenerative changes. A few small ova are distinctly seen inside the tubules among male germ cells.

Case 336.—Animal small, measuring only 56 millimeters from the vent to the tip of the snout. The external characters are those of a typical male; sides of throat pigmented, thumbs swollen, and vocal sacs present. The gonads are elongated, flattened, with highly lobulated lateral edges and with dark spots all around. They measure 9 millimeters long and 2.7 millimeters wide. Although wide, they are thick and heavy-looking, unlike a typical young ovary which is saclike, thin, light, and transparent. Vasa efferentia present, the ureters enlarged at the base forming a seminal vesicle. The Müllerian ducts are large and convoluted, especially at the basal part. The ureter and the Müllerian duct join each other before entering the cloaca.

In this animal, the gonads are ovotestes in which the ovarian and testicular elements are found in practically the same amounts (Plate 2, fig. 8). The testicular portion is composed of closely set normal seminiferous tubules with elements in active spermatogenesis. Mature spermatozoa are found in practically all of them. The ova vary in size. Some are large and show signs of degenerative changes, such as vacuolation and liquefaction of the cytoplasm. Some are medium sized and normal. The greatest number, however, are small, young, and spherical, and without any question, within the seminiferous tubules. The young ova are found everywhere, near the point of attachment

of the ovotestes, at the center, and at the periphery. Pigment cells and leucocytes are found around the large old degenerating ova, but they are never found around the small ones.

Case 340.—Animal small, measuring 54 millimeters from the tip of the snout to the vent. Secondary sex characters are typical male; the sides of the throat are pigmented, the thumbs are swollen, and vocal sacs are present. The right gonad is cylindrical, 9 millimeters long and 2 millimeters in diameter. The left gonad is also cylindrical, but it has an enlarged inflated portion about 3.5 millimeters in diameter which has a thin wall. In both cases the outer surface of the gonad shows slight tuberculations. Vasa efferentia are present on both sides, while the seminal vesicles are small and the Müllerian ducts are prominent and coiled, although not attaining the large size of those of the female (Plate 1, fig. 4).

The right gonad is an ovotestis with the testicular portion greater than the ovarian. The seminiferous tubules are normal-looking and contain all stages of multiplication, maturation, and spermiogenesis. The ova are mostly large, and their exact relation with the seminiferous tubules is hard to determine. The smaller ova are normal-looking. The largest ova, however, are in various stages of disintegration. The first indication of this is the appearance of very numerous fine granules of unknown character in the cytoplasm. These granules stain very dark with hæmatoxylin and may be scattered throughout the cytoplasm or may appear in large oval or elongated masses. The cytoplasm then begins to undergo vacuolation and liquefaction until the original position of the ova becomes a space now occupied by many small multinucleated leucocytes.

The left gonad is also an ovotestis. The unexpanded portions appear histologically similar to the right gonad. Although here the large ova are disintegrating, numerous small young ova are being proliferated from the walls of the seminiferous tubules intermingled with normal male germ elements.

The enlarged portion of this ovotestis shows that its inflated condition is due to the presence of one, two, or several "giant" tubules at the center, with enormous cavities occupying as much as two-thirds of the entire cross-section (Plate 2, fig. 5). These giant tubules may extend to the periphery of the ovotestis or they may be surrounded by small seminiferous tubules. The large lumina of the giant tubules are occupied by numerous

abnormally shaped spermatozoa scattered among granules mentioned above, leucocytes, and débris. The spermatocysts on the germinal epithelium of these giant tubules are loosely aggregated and much broken, especially at their distal sides, and the germ cells are in the process of disintegration and liquefaction. This condition is not in evidence in the germinal epithelium of the small, normal tubules. In addition to the male germ elements, small and apparently healthy ova are attached to the walls of the giant and small tubules.

Case 341.—Animal small, measuring 58 millimeters from the tip of the snout to the vent. Externally it possesses all the characters of the male; the sides of throat are pigmented, the thumbs are swollen, and vocal sacs are present. The right gonad is testislike in shape, more or less flattened. It measures 8 millimeters long and 2.1 millimeters wide and shows slight indentations on its lateral edge. The left gonad is 9 millimeters long and 2.2 millimeters wide and possesses deeper indentations. Vasa-efferential ducts are present on both sides; the seminal vesicle is not prominent; Müllerian ducts are coiled but much smaller than the oviduct of a normal female. The latter meet the ureters halfway between the posterior tip of the kidneys and the cloaca, so that they have a relatively long common tube (Plate 1, fig. 3).

Histologically, the right gonad is an ovotestis in which the testicular portion is much greater than the ovarian. The testicular portion is composed of seminiferous tubules of various sizes filled with male elements in all stages of spermatogenesis. Mature spermatozoa are invariably found inside these tubules. A few tubules are full of débris which is presumably the product of germinal disintegration. The female elements are represented by ova of various dimensions located in various regions of the ovotestis. Those at the middle of the gonad are large and show traces of destruction, while those situated at or near the periphery are small and normal-looking. Many of the latter are arranged in groups of four to ten and are distinctly seen located inside the tubules among male germ cells.

The left gonad shows almost a similar histologic condition, although here most of the ova are large (Plate 2, fig. 6). Also in this gonad more degenerate tubules full of débris and other products of male germ-cell disintegration are found. Many pigment cells and leucocytes are seen in the intertubular regions; they are especially abundant around large degenerating ova.

DISCUSSION

For the present it is very difficult to state definitely whether these ovotestes are normal in these frogs or these gonads are in a process of transformation from one sex to another. More-extended observation and experimental breeding are necessary to establish a definite conclusion.

These frogs fall under Division II, Group B, according to the classification adopted by Crew (1921). As numerous animals of this particular group come under our observation, we have a better chance to study the histologic conditions of the ovotestes. In our material the ovotestes may or may not be symmetrical. Although the two may depart to some extent from each other in size and shape, the proportionate amount of ovarian and testicular tissues found seems to be the same, so that if these gonads are in a state of transformation from one sex to another, the process must have been initiated simultaneously in the two gonads. The same can be said in general of the reproductive ducts. In practically all cases under observation, the ducts are more or less symmetrical.

Histologic studies of the ovotestes show that the male germ elements are invariably greater than the ovarian. The male germ elements are healthy and they appear to be the normal constituents of the gonads, while the ovarian tissues appear only here and there, scattered among male germ cells. This supposition is sustained by the fact that, while many of them are being produced and a great many have typical structures, many are in the process of disintegration. For a short time after being produced they retain the normal shape and structure of an ovum, but as they grow larger, they interfere not only with each other but also with other constituents of the gonads and thus lose their typical shape. The presence of leucocytes and pigments around degenerating ova may be also taken as a sign of the reaction of the organism to the existence of these atypical parts of the gonads.

Painstaking attempts fail to reveal a single point in the gonad where eggs are developed. On the contrary, young ova are seen given off from the walls of very many seminiferous tubules situated in various regions of the ovotestes. Crew (1921) mentions that ova may be found inside seminiferous tubules in European frogs and toads, but explains their presence in this position through an extrusion into the tubules from a primary position of the ova. Normally, however, only large ripe ova

are extruded, so that his supposition can be applied to the ovotestes under discussion only if all ova seen inside the tubules are large. In these ovotestes, small healthy young ova are found inside the tubules which appear normal in all respects. Many of these are attached to the walls of the tubules. Plate 2, fig. 7, shows a small sector of a tubule of frog 115 under high magnification, illustrating beautifully the ova under consideration. These cannot possibly have arisen from large degenerate ova as the latter are easily distinguished from the normal as these become highly vacuolated and distorted in shape without undergoing any reduction in size. Sooner or later they liquefy and become absorbed.

The conditions as found in *Rana vittigera* thus differ very markedly from those in European frogs and toads. In the latter no healthy ovarian tissues have been found included within the structure of healthy spermatic tissues (Crew, 1921). Crew explained this condition by saying that when ovarian tissues are healthy, that is to say, when they have not undergone appreciable degenerative changes, no considerable growth on the part of the spermatic tissue takes place. In these ovotestes, however, healthy spermatic and ovarian tissues are seen side by side inclosed in a common seminiferous tubule, similar to the condition reported by Guyenot and Ponse (1923) in toads. Of the two tissues, the spermatic is the more developed, while the ovarian tissues are being formed in many places.

Our study in the normal sex ratio in the larval and adult stages of *Rana vittigera* is not quite completed. Data up to the time of this writing, however, show that in the adult stage, during breeding or off-breeding seasons, there is a great preponderance of female individuals over the male. In places where male intersexual individuals are not encountered, the adult sex ratio is approximately 1 male to 1.47 females. In places where they are met often, the adult sex ratio runs as high as 1 male to 2.04 females. It is probably worth while mentioning in this connection that at one time, March 13, 1927, 156 externally male-looking frogs were collected together with 319 females; and, of the former, all except 7 have ovotestes. In fact, there are times of the year when we experience difficulty in obtaining males with typical normal testes. Such being the case, it appears that either there is a greater mortality of normal males in these frogs or the normal males may have transformed into males with ovotestes.

In *Rana vittigera*, the females are much larger than the males. The animals under consideration are small individuals with all external characters of the males; with gonads approaching the testis in size, shape, and contents; and with genital ducts approximating those of the male rather than those of the female. If these animals were originally females whose ovaries have transformed into testes recently, the following should have been found: (1) Larger individuals with ovotestes; (2) many individuals with a much greater ovarian tissue than spermatic; (3) some ovotestes that approach the ovary in shape more than the testis; (4) some ovotestes not connected with the kidney by the vas efferens; (5) some individuals with much better developed Müllerian ducts, with distinct openings to the cloaca and abdominal cavity. None of these, however, has been encountered.

If these individuals were originally females whose ovaries have started to transform into testes very early, it must be expected that in these ovotestes few or no young developing ova should have been found and that all ova should have been degenerate or degenerating as the gonads have transformed almost completely into testes. In our material, however, although mature spermatozoa are present everywhere, and the gonads are completely or almost completely testislike, the majority of the ova are either young and small or normal and large. Degenerating ova are relatively few, and these are not found in all ovotestes. It is also to be expected that if the transformation of ovary to testis has occurred very early, at least some Müllerian ducts should have been found showing a purely vestigial condition; that is, as fine straight strands of tissue as in normal males.

Both Witschi (1921) and Crew (1921) concluded in their work on intersexuality in frogs that there is a parallelism between the change in the development of the gonads and the change in somatic sex characters. The change in the somatic characters, however, takes place later than the change in gonadic contents (Lipschütz, 1924). Now in these frogs, all individuals show practically all external and internal somatic male characters, even if there is a preponderance of ovarian tissues (case 331) or when the ovarian and spermatic tissues are present in practically equal amounts (case 336). This goes to show that here the spermatic tissues have been in existence in the gonad much longer than the ovarian, and that the latter, although present in a greater amount in some specimens, presumably has not had sufficient time to cause the change in the somatic sex characters of the animal.

Case 340 may be considered as showing a process by which a solid structure of the testis may transform into a rather expanded thin-walled structure approximating that of an ovary. This process may have been initiated by the widening of the lumen of individual tubules or by the degeneration of certain tubules at the center of the testis so that their contents come to lie in a single large tubule. The end result in both cases, however, is the same where we find a giant tubule with an enormous lumen partly occupied by many degenerating male germ elements. Attached to the walls are still other male germ elements in the process of disintegration, while here and there, not far from the walls, we find healthy young ova.

The result of the findings of normal sex ratio in the adult stage of this particular group of frogs, the result of gross morphologic studies, and the result of the histologic study of their ovotestes suggest that, if these frogs are in a stage of sex-reversal, the course of transformation is from a male to a female, similar to what has been reported by Champy (1922) in *Triton alpestris* Laur. Of course, the previous history of these animals is not known, and more systematic and thorough breeding experiments are being done to test the validity of this assertion.

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ILLUSTRATIONS

[Drawings by H. A. Roxas.]

PLATE 1

FIG. 1. Camera lucida drawing of a cross section of a seminiferous tubule of frog 113, showing male and female germ elements. E. Leitz 15 × 16 mm.

2. Camera lucida drawing of a cross section of a tubule of frog 126, showing immature ova among healthy male germ cells. E. Leitz 15 × 16 mm.

3. Diagram of the urinogenital system of frog 341; × 2. *m*, Müllerian duct; *fb*, fat body; *ot*, ovotestis; *ve*, vas efferens; *k*, kidney; *sv*, seminal vesicle; *v*, cloaca.

4. Diagram of the urinogenital system of frog 340; × 2. Abbreviations as for fig. 3.

PLATE 2

FIG. 1. Cross section of the inflated portion of left gonad of frog 340, showing three "giant" tubules. Notice the degenerating sperms at the center of these tubules and the atypical spermatocyst of the germinal epithelium. Dissecting microscope 2 × a_0.

2. Camera lucida drawing of a portion of left ovotestis of frog 341, showing large ova among spermatozoa. E. Leitz 15 × 16 mm.

3. Camera lucida drawing of a portion of a tubule of frog 115, showing ova of different dimensions still attached to the wall of the seminiferous tubule. E. Leitz 15 × 4 mm.

4. A whole longitudinal section of the right ovotestis of frog 336, showing relative amounts of ovarian and spermatic tissues. Dissecting microscope 2 × a_0.

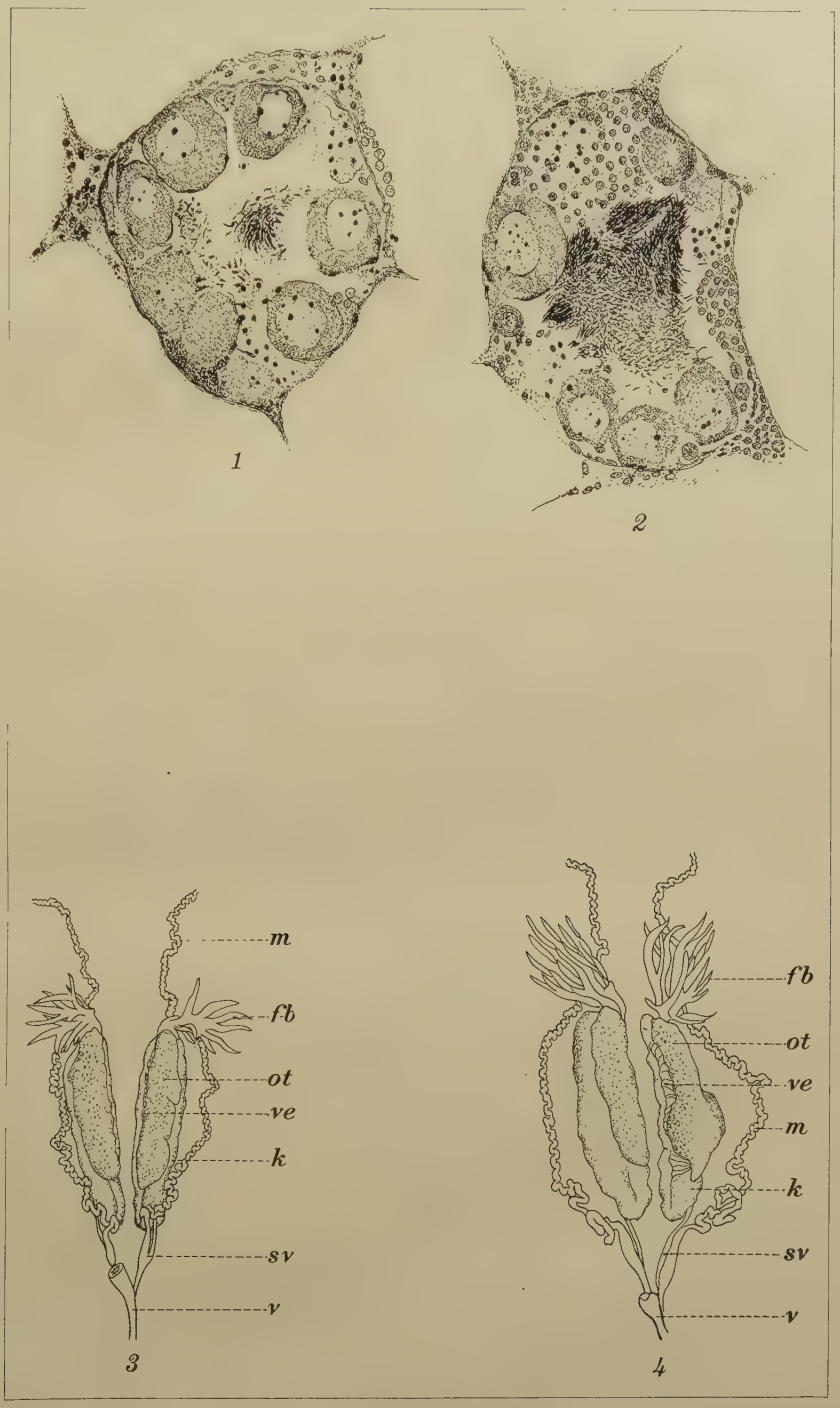
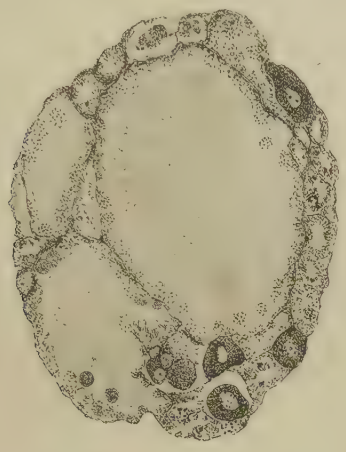


PLATE 1.



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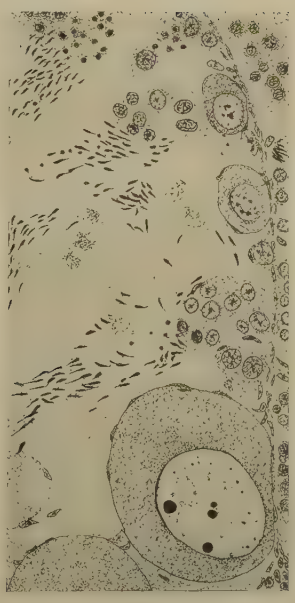

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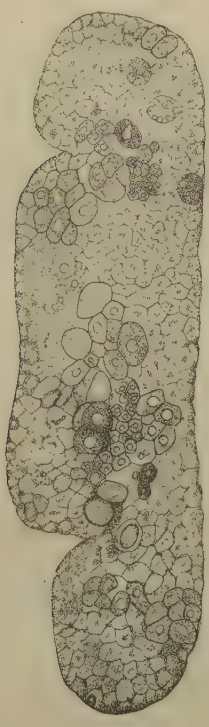

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PLATE 2.

SOME RELATIONS OF MAINTAINED TEMPERATURES TO GERMINATION AND THE EARLY GROWTH OF WHEAT IN NUTRIENT SOLUTIONS [1]

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TWO TEXT FIGURES

INTRODUCTION

In the autumn of 1918, the Committee on the Salt Requirements of Certain Agricultural Plants, appointed by the United States National Research Council, inaugurated a coöperative study of the growth of wheat plants in nutrient solution.(4) This prospective coöperation was to involve comparative experimental tests with a large number of nutrient solutions, the solutions differing according to a regular scheme. For a beginning several somewhat arbitrarily selected developmental phases of the wheat plant were to be studied. It was realized that a nutrient solution might be well suited for good growth during one phase of the plant's development and not so for another phase. It was also realized that a given nutrient solution may give good growth under one climatic complex and not under another, even though the second climatic complex might be well suited for growth with another nutrient solution. Briefly stated, it was planned to test different nutrient solutions under different climatic complexes.

The investigation here reported was carried out as a part of that general plan. It constituted a study of the growth of Marquis spring wheat in the germination phase, beginning with the exposure of the seed to the culture solution and continuing about five days, about as long as a wheat seedling under otherwise good conditions can maintain health in the absence of light. All tests were carried out in darkness, and seven different maintained temperatures were employed, each tested with one hundred twenty-six different nutrient solutions of the

[1] Botanical contribution from the Johns Hopkins University, No. 86.

3-salt type and also with distilled water. There were altogether 7 times 126, or 882, environmental complexes, and the series of tests was once repeated for all but the lowest temperature employed; 1,638 tests were carried out.

As it turned out, all the salt solutions used gave notably better growth than distilled water did, for all temperatures excepting the very lowest, with which the solutions and distilled water agreed on the whole in giving very little growth; but the different influences exerted by the different salt solutions for any maintained temperature were so variable, as appeared when the two tests of each solution were finally brought together and all solutions were compared for each temperature, that no clear and consistent relations could be discovered, from these experimental data, between growth vigor and solution composition. This is undoubtedly due to the fact that the solutions used were very dilute; if they had been of sufficiently higher concentration a clear series of relations between growth and solution composition for each temperature tested would probably have been evident. Since the numerical data secured were, therefore, not suited to a comparative study of salt influence the growth values were averaged for all solutions, for each temperature tested, and special attention was given to the very clear and consistent growth-temperature relations thus brought out. These temperature relations are the primary subject of the present publication.

The experimentation was performed in the Laboratory of Plant Physiology of the Johns Hopkins University, with financial aid from the Natioanl Research Council. The appreciative thanks of the writer are due to Prof. Burton E. Livingston for the facilities of his laboratory, for helpful advice in the experimentation, and for criticism of this paper.

EXPERIMENTATION

THE SOLUTIONS USED

The nutrient solutions used followed the plan above referred to. They are based on the scheme suggested by Livingston and Tottingham,(8) following the general outlines worked out by Schreiner and Skinner,(9) Tottingham,(11) Shive,(10) and other writers. The Livingston-Tottingham scheme embraces six types of solutions, each characterized by the three main salts employed, as follows:

Type I.	Type II.	Type III.
KH_2PO_4	K_2SO_4	KNO_3
$Ca(NO_3)_2$	$Ca(NO_3)_2$	$Ca(H_2PO_4)_2$
$MgSO_4$	$Mg(H_2PO_4)_2$	$MgSO_4$
Type IV.	**Type V.**	**Type VI.**
K_2SO_4	KNO_3	KH_2PO_4
$Ca(H_2PO_4)_2$	$CaSO_4$	$CaSO_4$
$Mg(NO_3)_2$	$Mg(H_2PO_4)_2$	$Mg(NO_3)_2$

Twenty-one nutrient solutions were employed in this study for each of the six 3-salt combinations, representing as many sets of salt proportions for each solution type. All told, there were one hundred twenty-six nutrient solutions. The solutions were approximately alike as to their total osmotic concentration or osmotic value, equivalent to 0.1 of an atmosphere of osmotic pressure. Each type of solution varied, however, in a systematic manner, as to the fraction of the total concentration any one of the constituent salts supplied. The unit employed in the calculation was one-eighth of the total concentration. In no case could any given salt supply less than one-eighth or more than six-eighths of the total salt concentration and it might supply any fraction of the total, from one-eighth to six-eighths. The Schreiner-Skinner triangle method of notation was employed, as developed in the plan. Table 1 shows the twenty-one salts for each solution type. The solutions were prepared from Baker Analyzed Salts and distilled water. Each one had, as has been noted, an osmotic value of about 0.1 atmosphere.

THE CULTURES AND THEIR TREATMENT

Although the wheat seed used was of a pure-line strain and although all grains were selected by hand and eye, considerable variation was encountered. However, it is probable that the selected grains exhibited much less variability (due to differences in internal conditions) than is generally shown by agricultural seed wheat of the Marquis variety.

Glass tumblers (capacity, about 300 cubic centimeters) were employed as culture vessels; each had a tightly stretched cover of thoroughly washed mosquito netting (of cotton thread, with open meshes about 2 millimeters square) tightly sealed to the outside of the tumbler wall by means of paraffin. Each of these net-covered tumblers was filled with the proper solution (or with distilled water), and twenty-five selected seeds were dis-

TABLE 1.—*Molecular proportions or fractions of total concentrations of constituent salts in nutrient solutions, the unit being one-eighth of the total concentration.*

Solution symbol.	Molecular proportions (eighths of total concentration).		
	Potassium salt.	Calcium salt.	Magnesium salt.
R1S1	1	1	6
R1S2	1	2	5
R1S3	1	3	4
R1S4	1	4	3
R1S5	1	5	2
R1S6	1	6	1
R2S1	2	1	5
R2S2	2	2	4
R2S3	2	3	3
R2S4	2	4	2
R2S5	2	5	1
R3S1	3	1	4
R3S2	3	2	3
R3S3	3	3	2
R3S4	3	4	1
R4S1	4	1	3
R4S2	4	2	2
R4S3	4	3	1
R5S1	5	1	2
R5S2	5	2	1
R6S1	6	1	1

tributed uniformly over the netting, the area of which was about 38 square centimeters. All seeds were in contact with the liquid, but none was submerged. Several methods of supporting the seeds and seedlings were tested in the preliminary part of the study, and this one proved best.

Each series of cultures involved only one type of solution but included twenty-one different solutions, each of these being represented by seven cultures. Each set of seven like cultures was distributed throughout the seven different temperatures tested, so that a single series comprised twenty-one solution cultures. All of the twenty-one nutrient solutions of any one solution type were thus simultaneously tested for each of the seven temperatures, and there were one hundred forty-seven solution cultures in each series. Each nutrient solution was renewed after each period of about twenty-four hours, for four renewals, the cultures being discontinued on the fifth day.

In a similar way tests were conducted on the germination of this wheat with distilled water for each of the temperatures and for equal periods of time as stated for the nutrient solutions.

The battery of chambers for temperature control at the Laboratory of Plant Physiology of the Johns Hopkins University, which has been described in its essentials by Livingston and Fawcett,(6) was used for this investigation. The seven temperatures employed were 13, 17, 21, 25, 28, 31, and 35° C. Variations from these values were never as great as 1°. The air humidity approached that of saturation for the given temperature in each chamber. Light was excluded as has been said.

Renewal of the solutions did not always occur at exactly 24-hour intervals, and the total length of the culture period was always less than five days, usually about one hundred ten hours. Variation from the time schedule was not great in any case, however, and all cultures of any series (twenty-one solutions of a single type, with each of the seven temperatures used) had the same time periods between renewals and the same total period. About eighty-six hours after the beginning of each series each shoot 1 centimeter long or longer was measured and record was made showing the number of seedlings in each culture that were 1, 2, 3, etc., centimeters high. All shoots were again measured after about one hundred ten hours, when the cultures were discontinued. To avoid much disturbance of the plantlets, the earlier measurements were correct only to a precision of about 1 centimeter, but the final measurements were more carefully made, to a precision of 1 millimeter, each seedling being removed from the solution at that time. These two measurements for each culture may be termed the "first" and the "second," occurring after about eighty-six and one hundred ten hours, respectively. The numerical results obtained for each culture were as follows: 1, Number of seedlings with shoots 1 centimeter or more high after about eighty-six hours; 2, approximate total shoot length (of all seedlings) after about eighty-six hours; 3, number of seeds germinated after about one hundred ten hours; 4, total shoot length (of all seedlings) after about one hundred ten hours; 5, total shoot elongation for the last twenty-four hours (obtained by subtracting 2 from 4, above).

The number of seeds germinated at the end of the whole period (3, above) may be taken to represent the seed viability for any culture; if this number is multiplied by 4 the product

represents the percentage of germination, since each culture had twenty-five seeds.

Each shoot-length total (2 and 4, above), divided by the corresponding number of seedlings measured, gives the average length of shoot for the seeds that had germinated in the culture in question. This quotient represents, in each case, the average shoot elongation per seed, omitting the seeds that failed to germinate. Finally, since the time periods were not exactly the same for all series, the quotient just mentioned was divided by the number of hours elapsed since the starting of the culture in question, thus giving the mean hourly rate of shoot elongation for the given culture. Subtracting the total shoot length for the shorter period (2, above) from the corresponding value for the longer period (4, above) gives a number representing the total shoot elongation for the last portion (about twenty-four hours) of the whole culture period (5, above). From this was obtained, as above, the mean hourly rate of elongation for the last portion of the period.

SALT RELATIONS

Of the forty-two tables of data that were obtained, only a list of the apparently best and apparently poorest solutions of each type, for the entire period of about one hundred ten hours, is here given for each temperature employed (Table 2). Data for only six temperatures are shown, those for the lowest temperature tested (13°) being omitted because growth was so low in that case as to render precision of measurement very low. In the category of apparently best solutions are included, for each type and temperature, only those that agreed for the two tests in giving mean hourly growth rates above the average for the series in which they occurred, and that showed differences not greater than 0.11 millimeter between the corresponding rates for the two tests. In the category of the apparently poorest are included, for each type and temperature, only those solutions that gave the lowest four hourly growth rates for their respective series for both tests, and that showed differences not greater than 0.11 millimeter between the corresponding rates for the two tests.

The data given in Table 2 were plotted on triangular diagrams in the usual manner, with a diagram for each temperature. In every case the solutions of either category (best or poorest) occupy scattered locations on the diagram, which makes it impossible to derive clear and consistent evidence regarding the salt relations. In order that any particular nutrient solu-

TABLE 2.—*Apparently best and apparently poorest solutions for shoot elongation for the entire 110-hour period, for each solution type, and for each maintained temperature employed.*

Solution type.	Temperature, 17°C.		Temperature, 21°C.		Temperature, 25°C.	
	Best solutions.	Poorest solutions.	Best solutions.	Poorest solutions.	Best solutions.	Poorest solutions.
I	R4S3	R1S2	R3S1	R2S2	R1S4	R2S2
	R5S1	R1S3	R4S2	R3S3	----	----
	----	R1S4	----	R3S4	----	----
	----	R2S2	----	R4S3	----	----
II	R4S3	R1S4	R1S3	R2S3	----	R4S3
	R5S2	R3S1	R4S1	R3S2	----	----
	----	----	R5S2	----	----	----
	----	----	R6S1	----	----	----
III	R2S2	R1S3	R2S5	----	R2S4	R4S2
	R3S4	R4S3	----	----	R2S5	R6S1
	R5S1	R5S2	----	----	----	----
IV	R5S1	R1S6	R1S3	R2S2	R1S2	R2S4
	R5S2	R2S1	R4S2	R2S3	R1S4	R5S2
	----	R2S3	----	R2S3	R1S5	----
	----	R2S4	----	R5S2	R2S1	----
	----	R3S2	----	R6S1	R2S2	----
	----	R3S4	----	----	----	----
V	R5S2	----	R1S3	R3S4	R1S4	R5S2
	----	----	R2S1	----	R4S2	----
	----	----	R5S1	----	----	----
VI	R3S4	R1S1	R5S1	R2S3	R1S4	R1S5
	R4S3	----	R5S2	R2S4	R4S2	R1S6
	R5S1	----	R6S1	R3S2	R5S1	----
	R6S1	----	----	----	R6S1	----

Solution type.	Temperature, 28°C.		Temperature, 31°C.		Temperature, 35°C.	
	Best solutions.	Poorest solutions.	Best solutions.	Poorest solutions.	Best solutions.	Poorest solutions.
I	R1S3	----	R5S2	----	R3S2	R1S1
	R1S4	----	----	----	R3S3	----
	R3S2	----	----	----	----	----
	R4S1	----	----	----	----	----
	R4S2	----	----	----	----	----
II	R1S2	R2S4	R1S3	R1S1	R2S5	R1S2
	R1S3	R2S5	R1S4	R4S3	R4S1	R3S1
	R1S4	R3S4	R1S5	----	R4S3	----
	R2S1	R5S1	R2S1	----	----	----
III	R1S4	R3S2	R1S1	R3S2	R1S5	R5S2
	R1S5	R5S2	R1S2	R4S2	R2S2	----
	R2S1	----	R1S3	R4S3	R2S4	----
	R2S2	----	R1S4	R6S1	----	----
	----	----	R1S5	----	----	----
	----	----	R3S3	----	----	----

TABLE 2.—*Apparently best and apparently poorest solutions for shoot elongation for the entire 110-hour period, for each solution type, and for each maintained temperature employed*—Continued.

Solution type	Temperature, 28° C.		Temperature, 31° C.		Temperature, 35° C.	
	Best solutions.	Poorest solutions.	Best solutions.	Poorest solutions.	Best solutions.	Poorest solutions.
IV	R1S4	R2S3	R1S1	R3S4	R1S3	----
	R1S5	R5S2	R2S1	R5S1	R1S5	----
	----	----	R2S5	----	----	----
	----	----	R5S2	----	----	----
V	R1S4	R6S1	R1S2	R5S2	R2S1	R1S5
	----	----	R1S3	----	R2S2	----
	----	----	R1S4	----	R4S2	----
	----	----	R2S1	----	R5S2	----
	----	----	R3S2	----	----	----
	----	----	R4S2	----	----	----
VI	R1S3	R1S5	R1S1	R2S1	R5S1	R1S6
	R3S4	----	R1S3	R2S2	R5S2	----
	R4S2	----	R3S1	----	R6S1	----

tion might be properly designated as one of the "best" or "poorest," in relation to specific salt effects, it would be logically necessary that the solutions shown as adjacent to it on the diagram should also be correspondingly relatively good or bad, according to the manner in which these adjacent solutions differed in salt proportions from the given solution. This necessity is not met by any of the diagrams, and these results therefore fail to show any clear picture of the salt relations dealt with. Consequently these important physiological relations cannot be discussed on the basis of the data of this study. If there were actually different influences exerted on the plantlets by the several solutions tested, their effects were masked by other influences; such as, the inherent variability of the seeds employed.

It is to be remembered that the solutions here used were very dilute, their osmotic value being only about 0.1 atmosphere, and that the culture period was very short, not extending beyond what is often regarded as the phase of seed germination. As has been said, if a sufficiently higher concentration had been employed it is probable that pronounced salt relations would have been brought out, even for this short culture period. It also seems safe to suppose that these very dilute solutions would have shown consistent differences if the culture period had been sufficiently long, but the period could not have been much longer without making light a necessary condition, with all the experimental difficulties that are thus implied.

Several somewhat vague suggestions, with regard to salt relations, were secured from the study of the triangular diagrams here referred to, and some of them have subsequently led to what appear to be valuable and valid results, secured with longer periods and with light included in the environmental complex. These results are reserved for other publications, however, since they cannot be based on the experimental data of the study now being reported.

In the present study the solutions all agreed in producing much higher growth rates than did cultures with the same maintained temperatures but with distilled water as the culture medium. This point will be discussed below, after the temperature relations for all solutions taken together are presented.

TEMPERATURE RELATIONS OF SOLUTION CULTURES FOR THE ENTIRE 110-HOUR PERIOD

Temperature clearly exerted a marked and consistent influence on the rate of germination and early growth of these wheat seedlings, in spite of the inherent variability in the seeds used. In such a study as this it would be desirable to study the temperature relations for each solution tested and then to study the influence of temperature on the influence of solution composition; that is, to compare the temperature relations of good and poor solutions, etc. Such a treatment might result in a very complete analytical survey of the influence of all environmental conditions if it were warranted by the experimental data. Since, however, the data here brought forward are of such nature as to preclude, for the present, a thorough-going study of the salt relations for any temperature, it is best to resort to a more general and less analytical survey of the temperature relations here shown. Instead of attempting to compare temperature relations for the different solutions, we study the general temperature relations for all of the solutions tested taken together; that is, for the whole range of the one hundred forty-seven sets of solution conditions or salt proportions employed. This amounts to saying that, for the purposes of this survey of temperature relations, we treat all solutions as though they were physiologically alike and derive a single grand average growth rate for each of the seven temperatures tested.

Table 3 presents the mean growth rate for the entire period of about one hundred ten hours for each solution type in each of the two tests and for each temperature. In the last column are given the grand averages, a single value for each temper-

ature. The minimum and maximum mean growth rates are given, as well as the average for each set of twenty-one cultures. The three values (in hundredths of a millimeter per hour shoot growth, for periods ranging from one hundred eight to one hundred fourteen hours) are given consecutively, separated by colons, as follows, minimum : average : maximum. The average for the several pairs of like tests (excepting for the lowest temperature, for which only one test was made) are shown in the next to the last column of the table, and the grand average for each temperature is given in the last column as has been noted. The grand averages bring out very clearly the facts that the highest rates of shoot elongation were obtaind with the maintained temperatures 28° and 31° (the values being about alike), that temperatures 25° and 35° gave rates markedly lower than those for 28° and 31°, and that temperatures 21°, 17°, and 13° gave still lower rates, these being progressively lower with lower temperatures. These grand averages will receive more attention farther on in this paper.

TABLE 3.—*Average hourly rates of shoot elongation for the entire culture period of about one hundred ten hours for all solution cultures and for each maintained temperature tested.*

[The rates are expressed in terms of hundredths of a milimeter.]

Temperature.	Solution type.	Length of period.		Minimum, average, and maximum hourly rate.[a]		Average of first and second tests.	Grand average.
		First test.	Second test.	First test.	Second test.		
°C.		*Hrs.*	*Hrs.*	*0.10 mm.*	*0.10 mm.*	*0.10 mm.*	*0.10 mm.*
13	I	114	-------	04:06:07	-------	-------	7
	II	108	-------	04:07:10	-------	-------	
	III	110	-------	03:04:06	-------	-------	
	IV	112	-------	04:06:08	-------	-------	
	V	108	-------	06:09:13	-------	-------	
	VI	108	-------	04:06:07	-------	-------	
17	I	114	112	14:20:23	21:25:29	22	24
	II	108	110	19:24:30	13:19:22	22	
	III	110	112	20:28:35	16:23:27	26	
	IV	112	110	12:20:25	19:23:26	21	
	V	108	114	32:39:47	17:25:33	32	
	VI	108	110	16:21:26	20:25:30	23	
21	I	114	112	32:38:46	37:46:52	42	42
	II	108	110	33:41:47	27:33:39	37	
	III	110	112	40:48:53	22:34:42	41	
	IV	112	110	32:36:42	36:43:49	40	
	V	108	114	44:57:67	35:46:57	51	
	VI	108	110	33:44:70	22:42:52	43	

[a] The first value given is the minimum, the second is the average, and the last the maximum.

TABLE 3.—*Average hourly rates of shoot elongation for the entire culture period of about one hundred ten hours for all solution cultures and for each maintained temperature tested*—Continued.

Temperature.	Solution type.	Length of period.		Minimum, average, and maximum hourly rate.[a]		Average of first and second tests.	Grand average.
		First test.	Second test.	First test.	Second test.		
°C.		Hrs.	Hrs.	0.10 mm.	0.10 mm.	0.10 mm.	0.10 mm.
25	I	114	112	43:50:61	48:57:66	55	55
	II	108	110	48:54:65	3?:45:49	50	
	III	110	112	43:59:68	43:53:62	55	
	IV	112	110	48:53:62	41:54:60	54	
	V	108	114	50:67:79	44:57:67	62	
	VI	108	110	48:58:65	38:52:62	54	
28	I	114	112	52:64:73	55:68:78	66	66
	II	108	110	55:63:84	45:58:79	61	
	III	110	112	53:70:86	49:63:89	67	
	IV	112	110	52:64:94	47:67:84	66	
	V	108	114	61:74:98	55:67:78	71	
	VI	108	110	57:70:84	50:63:75	67	
31	I	114	112	50:64:71	63:70:77	67	66
	II	108	110	50:63-77	52:67:82	65	
	III	110	112	49:69:78	53:67:78	68	
	IV	112	110	54:68:78	52:68:83	68	
	V	108	114	47:66:76	46:64:77	65	
	VI	108	110	63:74:85	54:62:70	68	
35	I	114	112	38:53:70	47:61:70	57	53
	II	108	110	23:47:61	40:51:60	49	
	III	110	112	25:57:71	37:52:61	55	
	IV	112	110	47:60:78	37:51:64	56	
	V	108	114	36:49:59	34:52:67	51	
	VI	108	110	43:51:59	41:48:65	49	

[a] The first value given is the minimum, the second is the average, and the last the maximum.

TEMPERATURE RELATIONS OF THE DISTILLED-WATER CULTURES FOR THE ENTIRE PERIOD OF ABOUT ONE HUNDRED TEN HOURS

In the second column of Table 4 are given the average results of the tests with distilled water, and the remainder of this table summarizes the corresponding results from the solution cultures, the latter from Table 3. The growth rates for the distilled-water cultures show the same general temperature relations as those shown by the highest rates, the lowest rates, and the grand averages for the nutrient-solution cultures. In all cases the rates for 28° and 31° are the highest and are about alike, those for 25° and 35° are lower and about alike, while those for 21°, 17°, and 13° are progressively still lower.

TABLE 4.—*Summary of hourly rates of shoot elongation for distilled-water cultures and nutrient-solution cultures for the entire period of about one hundred ten hours and for each maintained temperature tested.*

[The rates are expressed in terms of hundredths of a millimeter.]

Temperature.	Average hourly rate, both tests combined when there were two tests.			
	Distilled-water cultures.	Nutrient-solution cultures.		
		Highest rate obtained.	Lowest rate obtained.	Grand average.
°C.	*0.01 mm.*	*0.01 mm.*	*0.01 mm.*	*0.01 mm.*
13	7	13	3	7
17	16	30	18	24
21	22	58	13	42
25	31	72	46	55
28	36	86	51	66
31	33	80	46	66
35	30	68	38	53

It is to be especially emphasized that the distilled-water value is markedly lower in every case, with the single exception of that for 13°, than is the corresponding highest rate or the corresponding grand average value from the nutrient-solution cultures. Furthermore, the distilled-water value is somewhat lower than even the lowest rate from the nutrient-solution cultures in all cases, excepting for 13°. It appears from these results that the cultures with distilled water generally gave mean rates about half as great as the corresponding rates obtained with nutrient solutions. With the lowest temperature tested (13°, which is much too low for good growth of these plants) the distilled-water cultures gave a rate just equal to the grand average for this temperature with nutrient solutions.

All of the solutions tested were of about the same osmotic value (equivalent to about 0.1 atmosphere of osmotic pressure), and consequently one of the main features by which all solutions agreed among themselves and yet differed from distilled water is with regard to osmotic value. They also differed from water, and agreed among themselves, in that they all contained the six kinds of inorganic atoms or atomic groups (potential ions) known to be needed in considerable amounts by plants in general, although they did not contain these atoms and groups in the same proportions. It is clear that the presence of a slight osmotic value due to the salts used, or the presence of small amounts of the essential atoms and atomic groups in the solu-

tions, greatly improved the water for the kind of plant and the growth phase here dealt with. The water used was from a Barnstead still. It has generally been found to be free from copper or other highly poisonous impurity. It was not specially studied in connection with this work.

To the conclusions thus far reached may now be added these, that all the solutions used were much better suited to the germination and growth of this wheat than was distilled water. It is safe to emphasize the point, already considered by Shive,(10) that distilled water is not at all suitable as a germination medium when solution cultures are being studied, unless sickly plantlets are required.

The unsuitability of distilled water for seed germination, etc., has been emphasized and discussed by several other authors.[2] The injurious effect here shown was very probably due to outward diffusion of substances from the seed and seedlings. This conclusion follows the discussions of True and Bartlett,(13) and of True,(12) based on somewhat similar experiments.

TEMPERATURE RELATIONS OF SOLUTION CULTURES FOR THE LAST TWENTY-FOUR HOURS OF THE CULTURE PERIOD AND FOR THE EARLIER PART OF THE PERIOD

It is to be realized that the data for the temperature relations for the entire culture period (Tables 3 and 4) refer to actual shoot elongation only in part, for shoot elongation had not yet begun in the earlier part of the period. In a very general way, the data for the last twenty-four hours may be regarded as referring primarily to seedling enlargement, while those for the earlier portion of the period may be considered as referring largely to the preliminary processes generally considered together as seed germination. Therefore, it is worth while to study the average growth rates, not only for the entire period but also for the last twenty-four hours of the period and for the preceding portion also. Tables 5 and 6 present summaries of the growth-temperature data for all solution cultures, for these two partial periods. It is clear that the average rates shown in Table 5 (last twenty-four hours) are in general much larger than the corresponding ones shown in Tables 3 and 4 and in Table 6. The notations of Tables 5 and 6 are self-explanatory.

[2] A résumé of the literature on the physiological properties of distilled water, up to the time of its publication, is given in the paper by B. E. Livingston et al.; (4) see also True and Bartlett.(13)

TABLE 5.—*Average hourly rates of shoot elongation for the last twenty-four hours of the culture period, for all solution cultures and for each maintained temperature tested.*

[The rates are expressed in terms of hundredths of a millimeter.]

Temperature.	Solution type.	Mean hourly rate.			Grand average.
		First tests.	Second tests.	Average, first and second tests.	
°C.		*0.01 mm.*	*0.01 mm.*	*0.01 mm.*	*0.01 mm.*
13	I	27	----------	27	30
	II	31	----------	31	
	III	24	----------	24	
	IV	26	----------	26	
	V	40	----------	40	
	VI	27	----------	27	
17	I	72	84	78	82
	II	90	91	90	
	III	83	75	79	
	IV	75	----------	75	
	V	100	----------	100	
	VI	----------	87	87	
21	I	104	126	115	112
	II	126	110	118	
	III	101	96	99	
	IV	108	101	105	
	V	120	115	118	
	VI	104	123	114	
25	I	140	140	140	137
	II	135	137	136	
	III	138	124	131	
	IV	140	124	132	
	V	153	141	147	
	VI	130	138	134	
28	I	151	149	150	157
	II	158	158	158	
	III	160	156	158	
	IV	154	152	153	
	V	166	158	162	
	VI	162	160	161	
31	I	143	149	146	153
	II	148	165	152	
	III	156	140	148	
	IV	162	145	153	
	V	153	158	155	
	VI	165	156	161	
35	I	118	126	122	124
	II	121	137	129	
	III	123	118	121	
	IV	134	114	124	
	V	128	131	129	
	VI	121	121	121	

TABLE 6.—*Average hourly rates of shoot elongation for the first part (about eighty-six hours) of the culture period, for solution cultures and for each maintained temperature tested.*

[The rates are expressed in terms of hundredths of a millimeter.]

Temperature.	Solution type.	Mean hourly rate.			Grand average.
		First test.	Second test.	Average, first and second tests.	
°C.		*0.01 mm.*	*0.01 mm.*	*0.01 mm.*	*0.01 mm.*
17	I	7	9	8	9.5
	II	5	----	5	
	III	12	9	11	
	IV	8	----	8	
	V	16	----	16	
	VI	9	----	9	
21	I	20	23	22	23
	II	17	13	15	
	III	29	29	29	
	IV	18	23	21	
	V	33	23	28	
	VI	24	20	22	
25	I	30	33	32	32
	II	31	23	27	
	III	38	33	36	
	IV	31	33	32	
	V	38	32	35	
	VI	35	28	32	
28	I	41	46	44	40
	II	34	33	34	
	III	40	36	38	
	IV	38	40	39	
	V	44	40	42	
	VI	41	37	39	
31	I	40	47	44	42
	II	40	34	37	
	III	44	47	46	
	IV	43	44	44	
	V	38	37	38	
	VI	46	37	42	
35	I	35	41	38	31
	II	27	25	26	
	III	38	34	36	
	IV	36	32	34	
	V	26	27	27	
	VI	28	26	27	

The general temperature relations shown in Tables 3 and 4 are seen to hold also for Tables 5 and 6. The mean hourly rates given in the last table are, of course, much lower than the corresponding ones for the last twenty-four hours (Table 5) and

they are notably lower than those for the entire period (Tables 3 and 4). The next section will be devoted to a comparison of these three sets of growth-temperature data by means of graphs.

GRAPHS OF THE GROWTH-TEMPERATURE RELATIONS

The data of Tables 4, 5, and 6 are set forth graphically in fig. 1, which it will be noted includes a graph of the entire-period data for the distilled-water cultures. These graphs have been

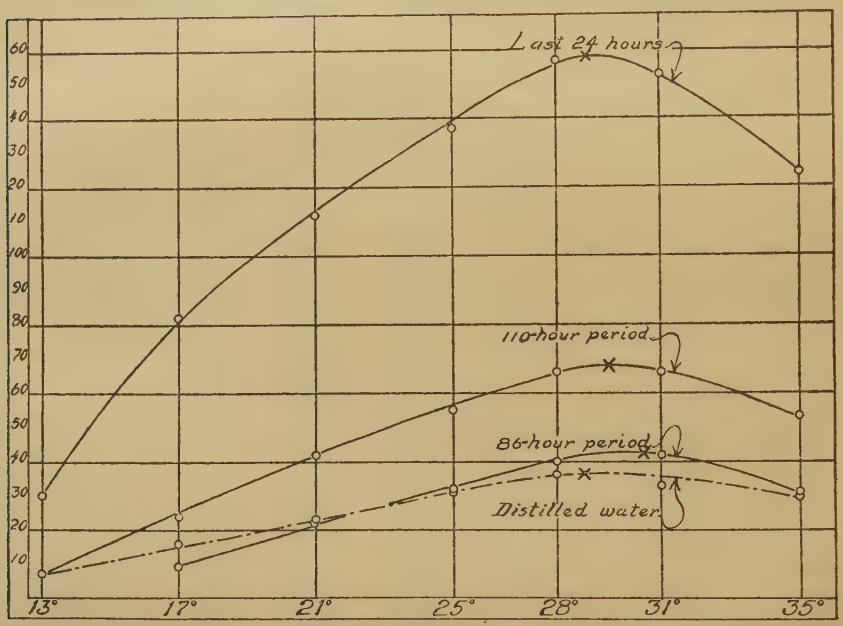

FIG. 1. Graphs showing the relation of maintained temperature to the mean hourly rates of shoot elongation in the solution cultures, for the entire culture period (about one hundred ten hours), for the last twenty-four hours of the period, and for the first part of the period (about eighty-six hours); and also for the distilled-water cultures for the entire period. Temperatures are shown by abscissas and growth rates by ordinates. Data are from Tables 3, 4, 5, and 6. An × on each graph indicates the approximate position of the maximum growth rate and the corresponding abscissa indicates the approximate position of optimal temperature on the thermometer scale.

subjected to only a very slight amount of smoothing and even that was hardly necessary; the ordinate values taken from the tables form remarkably smooth and consistent curves. As has been stated above, all three series of grand averages for the solution cultures (for the whole period, for the last twenty-four hours, and for the first part of the period) agree in showing the highest growth rates for maintained temperatures of 28° and 31°, and the values for these two temperatures are nearly alike in all three cases. The same is true for the averages from the

distilled-water cultures. From these observations, and from the graphs of fig. 1, it seems to be clear that the optimum temperature for the germination of these wheat seeds and for early shoot growth of the resulting seedlings in darkness lay between 28° and 31°, surely not above 31° nor below 28°. Assuming that the graphs are closely representative of the actual statistical data on which they are based, it appears from their curvatures that the optimum for the solution cultures was about 29° for the last twenty-four hours of the period, about 30.5° for the preceding part of the period (about eighty-six hours), and about 29.5° for the entire period. For the distilled-water cultures and for the entire period the optimum is shown as lower than in any other case, about 28.5°. Perhaps these differences are not significant and 29.5° may safely be taken as a very close approximation to the optimum from all four sets of data. Had the seedlings been allowed to develop farther, it is probable that the difference between the optimum for the early and for the later part of the period would have been of greater magnitude. Lehenbauer(3) has discussed an alteration of the optimum temperature as development proceeds in seedlings of maize.

An interesting point brought out by these graphs is that each curve is very nearly symmetrical about the vertical line that passes through its maximum. This does not appear to be generally true in growth and other biological processes; in many cases reported in the literature (see Lehenbauer,(3) just mentioned, for example; also Kanitz(2) and Fawcett(1)) the upward slope of this sort of graph is more gradual than the downward slope.

The average hourly growth rate for any temperature is seen to be very much greater for the last twenty-four hours of the period than for the entire period; and this, in turn, is notably greater than the rate for the first eighty-six hours. This must follow from the fact that the earlier portion of the experiment period was devoted to germination activities on the part of the seeds, while shoot elongation became prominent only after a considerable portion of the period had elapsed. The data for the last twenty-four hours really refer to young plantlets rather than to germinating seeds, as has been noted.

These graphs, like the data from which they are derived, fail to give any definite indication as to the minimum and the maximum temperature for germination and growth. With considerable more labor these two critical points might have been

determined approximately, but this study was not planned to deal with temperature maxima and minima.

In the preparation of wheat seedlings, from seeds like those used in this study, for solution culture and other experiments, it may be recommended that a maintained temperature between 29° and 30° be employed, if the most rapid shoot elongation in darkness is desired. If temperature is not maintained its fluctuation should not greatly exceed the range between 28° and 31°. It must of course be borne in mind that this recommendation is based on these particular tests. Such statements as this need to be carefully guarded, to avoid the possibility of a generalization being carried farther than is warranted by the facts in hand. Other temperature relations may perhaps be discovered for other lots of wheat seed and probably for other media than those here tried. It is especially worthy of note that these same sets of salts and salt proportions (or any one of these sets) might possibly exhibit significantly different temperature relations if longer test periods were employed or if the osmotic value of the solutions used were sufficiently higher than here dealt with. The present paper is calculated to go beyond what is really shown by the experimental results only in so far as interpolations have been made for temperatures not tested, in the graphs of fig. 1. The smooth form of the curves appears to warrant their use for interpolations.

TEMPERATURE COEFFICIENTS OF SHOOT ELONGATION

A very satisfactory method for picturing at least some important aspects of the temperature relations of any process is the method of temperature coefficients.[3] The temperature coefficient for a given process and for a given temperature interval is the quotient obtained by dividing the process rate for the higher temperature by that for the lower. The interval is conveniently taken as 10° C., and the coefficient is generally represented by the symbol Q_{10}.

The values for Q_{10} were obtained for shoot elongation in these seedlings, for all the 10° intervals available by whole degrees, and for the entire period and the two parts of it. From each solution graph of fig. 1 was determined the approximate hourly rate for each temperature from 13° to 35°, by whole degrees. This rate for the 24-hour period and for 13° is 0.29 millimeters

[3] For literature on this subject see Livingston and Shreve (7) and the references there given; see also Kanitz, Lehenbauer, and Fawcett, cited above.

and that for the same period and for 23° is 1.30 millimeters, so that Q_{10} (13°–23°) is 1.30 divided by 0.29, which is 4.5. The values of Q_{10} for all the 10° ranges of the three test periods (the last twenty-four hours, the preceding eighty-six hours, and the entire one hundred ten hours) are given, by whole numbers of degrees, in Table 7, which is self-explanatory.

TABLE 7.—*Ten-degree temperature coefficients* (Q_{10}) *for shoot elongation for the last twenty-four hours of culture period, for the entire period, and for the first eighty-six hours.*

Temperature interval.	For last 24 hours.			For entire period (110 hours).			For first 86 hours.		
	Hourly rate for—		Q_{10}	Hourly rate for—		Q_{10}	Hourly rate for—		Q_{10}
	Higher temperature.	Lower temperature.		Higher temperature.	Lower temperature.		Higher temperature.	Lower temperature.	
°C.	*0.01 mm.*	*0.01 mm.*		*0.01 mm.*	*0.01 mm.*		*0.01 mm.*	*0.01 mm.*	
13–23	126	30	4.2	49	7	7.0	28	-------	-------
14–24	133	44	3.0	52	11	4.3	30	-------	-------
15–25	140	58	2.4	55	16	3.4	32	-------	-------
16–26	146	70	2.1	60	20	3.0	37	-------	-------
17–27	151	82	1.8	63	25	2.5	39	10	3.9
18–28	155	91	1.7	66	29	2.3	40	12	3.3
19–29	157	99	1.6	67	33	2.0	42	16	2.6
20–30	156	106	1.5	66	37	1.8	43	19	2.3
21–31	153	113	1.4	66	42	1.6	42	23	1.8
22–32	146	120	1.2	63	45	1.4	40	25	1.6
23–33	139	126	1.1	61	49	1.2	37	28	1.3
24–34	131	133	1.0	57	52	1.1	34	31	1.1
25–35	124	140	0.9	53	55	1.0	31	32	1.0

It has been customary to discuss temperature coefficients as though they were constant for each process, at least constant for a considerable range of temperature ranges, and the "van't Hoff principle" in this connection has been stated to the effect that chemical processes have a value of Q_{10}, about 2.0 or 2.5. As Fawcett has emphasized, however, the value of Q_{10} for any process whatever varies in magnitude from infinity to zero, and the process is best characterized (as to its temperature relations) by showing just how this variation occurs. For the growth data here considered this is readily shown by graphs such as those presented in fig. 2, in which the several temperature ranges are abscissas and the coefficient values are ordinates. Inspection of these graphs shows that the temperature coefficients for shoot growth in these seedlings follow the general law for such coefficients; for low-temperature intervals the value

is of course very high and for high intervals it is very low, but the graphs extend only from interval 13°–23° to interval 25°–35° for the entire period and the last twenty-four hours, and from interval 17°–27° to interval 25°–35° for the first eighty-six hours. Like all other processes (whether physical or chemical), this process of shoot growth shows one interval in each graph for which the value of Q_{10} is about 2.5; but this interval is not the same in the three cases. For the last 24-hour period it is between 15° and 25°, for the 110-hour period it is between 17° and 27°, and for the 86-hour period it is between 19° and 29°.

These differences illustrate the fact, already emphasized by other writers that the Q_{10} value, for any 10° temperature interval with a finite value of the coefficient, varies not only with the particular 10° temperature range for which it is calculated but also with the nature of the process dealt with. For the three cases at hand the form of the coefficient graph appears to have been determined (as Lehenbauer also found, for maize seedlings) by the length of the experiment period. This probably means that the form was determined by internal conditions, by the particular type of growth that was involved for each period.

Any kind of plant growth (such as shoot elongation, which was measured in these studies) is of course the resultant of many component physiological processes, and the temperature relation of the resultant growth must be considered as the resultant of the temperature relations of all the component processes taken together. It is not yet possible to attempt any promising study of the many components, but we readily secure evidence that there is a definite relation, as shown by the graphs of temperature coefficients, between temperature and the resultant complex, measured as growth. Also, for any instant in the development of plants such as those here considered the growth rate may be different from that for any other instant; the rate begins very low, is more or less gradually accelerated for a time and is finally retarded until it ceases altogether. For this grand march of the growth rate there may, of course, be one or more longer or shorter periods during which the rate does not alter perceptibly, and it may increase and decrease several times before coming to a stop. On the grand march of the growth rate, which is considered as determined by internal conditions for any given set of external conditions, is always superimposed, in nature, the influence of the fluctuating surroundings; but

these cultures are considered as having all been treated alike in all respects excepting for the differences in maintained temperature. The original internal differences from seed to seed and the chemical differences from solution to solution are considered as having been overcome, for our purposes, by the process of averaging that gave the growth rates before us. Therefore, the differences between the three curves of fig. 2 represent

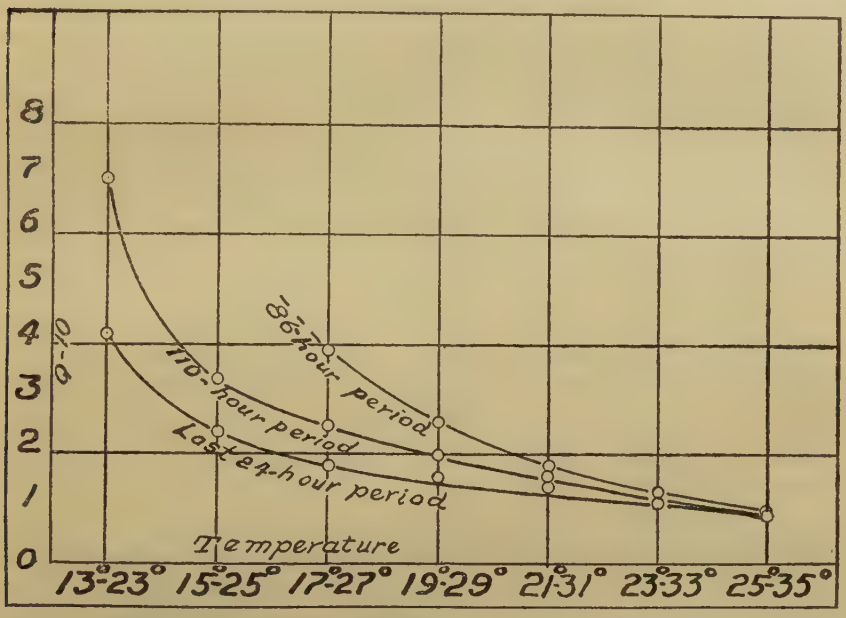

FIG. 2. Graphs of 10° temperature coefficients (Q_{10}) of shoot elongation for the three lengths of culture period. The different temperature intervals are indicated on the axis of abscissas and the values of Q_{10} are shown by the ordinates. Data from Table 7.

differences between the mean physiological states of the plantlets for the first eighty-six hours, for the entire period, and for the last twenty-four hours. The three curves represent three different ranges of the march of shoot elongation, and the temperature coefficient of the mean growth rate for one range alters from interval to interval in a way different from that followed by the coefficient for the mean growth rate for another range. The three periods differ in this respect somewhat as though three different kinds of organisms were represented.

It is interesting to note that the coefficient curve for the entire temperature range dealt with, rises most rapidly in the case of the earlier part of the period and least rapidly in the case of the later part of the period, while it has an intermediate

position in the case of the entire period of about one hundred ten hours. If the 86-hour period had been sufficiently longer, or if the 24-hour period had been sufficiently shorter, the three curves might have been equidistant from one another in the abscissa region represented by the available data. All three curves approach having a common ordinate of unity for the temperature interval from 24.5° to 34.5°, which is additional evidence that the optimum temperatures for all three lengths of period lay in the vicinity of 29.5°. If very narrow temperature intervals were used, instead of intervals of 10°, it should be possible in this way to fix the optimum temperature corresponding to each curve with any desired degree of precision, for the optimum temperature is clearly the middle point of a very narrow temperature interval for which the coefficient value is unity. This might be accomplished mathematically.

SUMMARY

The study reported in this paper was undertaken in connection with a plan for coöperative research on the salt requirements of plants, under the auspices of a committee of the Division of Biology and Agriculture of the National Research Council. The early growth of Marquis wheat was studied, for seven maintained temperatures (13, 17, 21, 25, 28, 31, and 35° C.) and for the first five days after the soaking of the seed began. One hundred twenty-six 3-salt solutions were used, containing the main essential chemical elements in different proportions but all having the same total osmotic value (equivalent to 0.1 atmosphere of osmotic pressure). Distilled water was also used. Twenty-five selected seeds were used in each test, and all tests were repeated once. The seeds rested on paraffined cotton-thread netting stretched at the surface of the liquid and all were in contact with the liquid, but none was submerged. The constant-temperature chambers showed less than a degree of fluctuation. Light was excluded.

The results indicate that all of the solutions tested were about equally satisfactory for the germination and very early growth of this seed; the range in salt proportions was large, but no solution showed clear evidence, on the whole, of giving better growth than any other. More-concentrated solutions or a longer experiment period might be expected to show differences. All of the solutions are to be regarded as about alike in their suitability for producing seedlings 4 or 5 centimeters high. On the other hand, the solutions all agreed in giving much better growth

than did distilled water, for all temperatures tested excepting the lowest, for which all growth rates were very slow.

Since all solutions were to be considered as nearly alike, the results of all solution cultures for each temperature were averaged, to secure an average hourly rate of shoot elongation for the entire period (about one hundred ten hours), for the first eighty-six hours, and for the last twenty-four hours. For all three periods the optimum temperature, as shown by these averages, lay between 29° and 30°, and any temperature between about 28° and 31° may be expected to give about the maximum rate of development for such seeds and solutions as those used. To produce seedlings with shoots about 4 centimeters high, with optimum temperature, a period of about ninety-five hours was required after the seeds were placed in contact with the solution, or a period of about twenty-five hours after the shoots emerged from the seed coats. From the graphs of this paper temperatures may be selected to give any desired rate of shoot elongation.

The average hourly rates of shoot elongation for the three periods and for each of the temperatures employed are as follows, expressed in terms of hundredths of a millimeter:

	Temperature, °C.						
	13	17	21	25	28	31	35
For first part of period, about 86 hours (solutions)		9.5	23	32	40	42	31
For last 24 hours of period (solutions)	30	82	112	137	157	153	124
For entire period of about 110 hours (solutions)	7	24	42	55	66	66	53
Distilled water	7	16	22	31	36	33	30

No relation was shown either between solution composition and the viability of the seeds or between this and temperature.

The growth-temperature graphs are nearly symmetrical about the vertical line for the temperature 29°.

The temperature coefficients of shoot elongation for temperature intervals of 10° and for the three periods are shown as graphs. All three coefficient values are close to unity for the 10° interval centering at 29.5° (about the optimum temperature). For lower temperatures the curvatures of the three coefficient graphs are very different. For the interval centering at 22° the coefficient values are as follows: First eighty-six

hours, 3.9; entire period, 2.5; last twenty-four hours, 1.8. These differences reflect alterations in the nature of the process measured, as time went on; shoot elongation was not measurable for the earlier hours and it became rapid for the later ones.

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ILLUSTRATIONS

TEXT FIGURES

FIG. 1. Graphs showing the relation of maintained temperature to the mean hourly rates of shoot elongation in the solution cultures, for the entire culture period (about one hundred ten hours), for the last twenty-four hours of the period, and for the first part of the period (about eighty-six hours); and also for the distilled-water cultures for the entire period. Temperatures are shown by abscissas and growth rates by ordinates. Data are from Tables 3, 4, 5, and 6. A cross on each graph indicates the approximate position of the maximum growth rate, and the corresponding abscissa indicates the approximate position of the optimal temperature on the thermometer scale.

2. Graphs of 10° temperature coefficients (Q_{10}) of shoot elongation for the three lengths of culture period. The different temperature intervals are indicated on the axis of abscissas and the values of Q_{10} are shown by the ordinates. Data from Table 7.

PHOTOMICROGRAPHS OF PHILIPPINE STARCHES

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TEN PLATES

INTRODUCTION

Although the Philippine Islands have many varieties of starch-producing plants, both cultivated and wild, about 3,000,000 kilograms of starch, worth over 500,000 pesos, are imported annually, according to Bureau of Customs reports.[1] At present, there is not a commercial starch factory in the Islands.

Although some analyses of sweet potatoes [2] and other Philippine tubers [3] have been made, only a very few photomicrographs of Philippine starches are recorded in the literature.[4] The present investigation was undertaken for the purpose of preparing photomicrographs of starch grains from Philippine tubers. The results show that, in general, starches from different specimens of the same species are very similar in microscopic appearance, while starches from different species are usually quite unlike.

MATERIALS

Starches were prepared from one hundred two samples of tubers and one cycad trunk, comprising fourteen species in all, grown in different parts of the Islands and under varying conditions. The several samples were obtained as the fresh roots, mainly from the various Government experiment stations through the coöperation of Dr. Stanton Youngberg, director of the Bureau of Agriculture, and Mr. A. F. Fischer, director of the Bureau of Forestry, who courteously extended the resources of their organizations in the procurement of the material needed.

In nearly all cases, leaves and stalks accompanied the tubers and were identified botanically by Dr. L. M. Guerrero, of the

[1] Annual Report of the Insular Collector of Customs (1923–1926), Bureau of Customs, Manila.

[2] Labayen, S. D., Philip. Agriculturist and Forester 3 (1914) 79–80.

[3] Quisumbing, F. A., Philip. Agriculturist and Forester 3 (1914) 85–98 and 99–110.

[4] Bacon, R. F., Philip. Journ. Sci. § A 3 (1908) 93–98.

Bureau of Science, in order to avoid the inaccuracy and confusion of the multiplicity of common names in the various dialects of the Philippines. The tubers were also planted in a garden in the Bureau of Science grounds and botanical specimens grown for a further check. Description of the plants and tubers are given by Wester [5] and by Brown.[6]

EXPERIMENTAL PROCEDURE

PREPARATION OF THE STARCHES

Practically pure starches were prepared by peeling the tubers, grinding or grating the flesh, straining through muslin, settling, and washing. The grinding was done with either a large nutmeg grater or an ordinary kitchen food grinder, as expediency suggested. Washing was accomplished by settling and decanting three times in tap water and two or three times more in distilled water, or until the starch was as nearly white as possible; finally, the material was washed with alcohol followed by ether on a Buchner funnel connected to the vacuum line. The starches were then dried in vacuum desiccators over calcium chloride or sulphuric acid.

Most of the starches settled out quickly and were white, but some of the tubers were mucilaginous and their starches persistently brown; these conditions are specifically mentioned under the description of the individual species. In the case of the more-mucilaginous tubers, the starch would remain in suspension in the liquor for days. To overcome this difficulty a Sharples laboratory supercentrifuge was installed and operated from the compressed-air line. This apparatus proved a successful solution of the problem, although the ubi starches so prepared still retained a brown color. All the slimy liquors, such as those obtained from ubi, gabi, and biga, were run through this machine. In some cases it was apparently impossible to separate starches by any other means, and in others, the machine tended to expedite the settling process and save time.

Five of the starch samples, as mentioned in the individual descriptions, were prepared by Dr. H. I. Cole, who started this research just prior to leaving the Bureau of Science to assume the position of chief chemist of the Culion Leper Colony.

[5] Wester, P. J., Philip. Agr. Rev. 14 (1921) No. 3.
[6] Brown, W. H., Bull. P. I. Bur. Forestry 21 (1920).

METHODS OF ANALYSIS AND DIFERENTIATION

Photomicrographs were taken of each starch in ordinary and in polarized light, with a magnification of 300 diameters. Data concerning the different conditions for the individual photographs are given in Table 1.

TABLE 1.—*Conditions under which photomicrographs were taken.*

Figure No.	Name.	Light.[a]	Illuminant.	Mount.	Filter.
1	Kamote	O	100-watt Mazda	Water	None.
2	do	P	do	do	Do.
7	Biga	O	Pointolite	do	Yellow and blue.
8	do	P	Arc	Canada balsam	None.
9	Gabi	O	Pointolite	Water	Blue.
10	do	P	Arc	Canada balsam	None.
11	Palauan	O	Pointolite	Water	Blue.
12	do	P	Arc	Glycerine	None.
13	Ubi	O	Pointolite	Water	Yellow and blue.
14	do	P	do	do	Blue.
17	Tugi	O	do	do	Yellow and blue.
18	do	P	Arc	Canada balsam	None.
21	Lima-lima	O	Pointolite	Water	Yellow and blue.
22	do	P	do	do	Blue.
23	do	O	do	do	Yellow and blue.
24	do	P	do	do	Blue.
30	Aroro	O	do	do	Yellow and blue.
31	do	P	do	do	Blue.
32	Yab-yaban	O	do	do	Yellow and blue.
33	do	P	do	do	Blue.
34	Nami	O	do	do	Yellow and blue.
35	do	P	do	do	Blue.
36	Kamoting-kahoy	O	do	do	Do.
37	do	P	do	do	Do.
40	*Dioscorea flabellifolia*	O	do	do	Yellow and blue.
41	do	P	do	do	Blue.
42	*Cycas* sp	O	do	do	Yellow and blue.
43	do	P	do	do	Blue.
44	Mayatbang	O	100-watt Mazda	do	None.
45	do	P	do	do	Do.

[a] O, ordinary light; P, polarized light.

Two ordinary microscopes with polarizing attachments were used interchangeably. The cameras used were a Carl Zeiss 5 by 7 vertical model, a large horizontal Zeiss with arc illumination, and for a few of the photographs a Leitz Makam (9 by 12 centimeters); the last is a small, light camera, which is supported by the draw tube of the microscope itself. The vertical form of camera was preferred when using water mounts as it minimized

the movement of the starch grains and mounting medium, and the Pointolite lamp was found the most convenient illuminant.

Glycerine was found to be an excellent mounting medium for photographs in polarized light since its viscosity tends to minimize the motion of the smaller, more-mobile grains and permits the use of horizontal apparatus through lessened flowing of the medium from under the cover glass. It is rather more convenient for quick preparation than Canada balsam. Fuchsin and iodine stains were tried but not used.

The size of the starch grains was measured by an ordinary ocular micrometer. The smallest and largest sizes observed are given, together with the estimated average or commonest size. Careful examination has shown that the starch grains produced by a particular plant are remarkably constant in size, shape, and general characters.[7]

When the hilum is not in the center of the grain, its location is indicated "by measuring the distance between it and the nearer, as well as the further margin of the grain and stating the ratio between these figures, which expresses the degree of eccentricity, as a fraction. Thus in potato starch, the greater distance is about five times the lesser, and the eccentricity is, therefore, about $\frac{1}{5}$."[8] The center of the cross in polarized light is taken as coincident with the hilum. Photomicrographs and histological characteristics are given here as means of identification rather than chemical and physical tests. Specific reactions, such as with ferric chloride, chloral hydrate, etc., as used by Reichert[9] and by Planchon and Juillet[10] were tried but not given much emphasis as they were considered of rather less value. Tests for cyanogenetic glucosides, using sodium picrate, were made[11] to ascertain which of the tubers were poisonous. Cassavas were the only positive ones.

A satisfactory method of determining the percentage of starch in tubers is given under the discussion of the starch from

[7] Greenish, H. G., The Microscopical Examination of Foods and Drugs (1923) 1.

[8] Greenish, op. cit. 4.

[9] Reichert, E. T., The Differentiation and Specificity of Starches in Relation to Genera, Species, etc. (1913).

[10] Planchon, L., et A. Juillet, Étude de Quelques Fecules Coloniales (1910).

[11] Allen's Commercial Organic Analysis 7 (1913) 470.

yab-yaban. No special effort was made to secure a quantitative yield of starch in the extraction from the tubers, since quantitative analyses of most of the tubers have been made by previous workers, whose results are quoted here. In a few cases records were made of the percentage of dry starch obtained from weighed amounts of the fresh, peeled tubers. This was only possible when the tubers were received soon after harvesting; many of them were shipped to Manila by interisland boat and were a week or two in transit, with consequent loss of moisture.

A complete, efficient extraction of the starch was not obtained or sought, but since all tubers were treated as nearly as possible in the same manner, the figures in Table 2 will give an idea of the relative ease or difficulty of extraction. They should not be taken as showing the yield that might be obtained in an efficient commercial starch factory, as they are too low.

The six moisture determinations in Table 3 are given simply as a guide to the amount of water that may be expected in such tubers.

TABLE 2.—*Yield of dry starch from the wet peeled tubers.*

Name.	Number of samples.	Yield.	
		Range.	Average.
		Per cent.	*Per cent.*
Kamote	6	7.5–15.5	12.4
Biga	1	16.4	16.4
Gabi	5	1.4–16.7	9.1
Wild ubi	1	8.1	8.1
Yab-yaban	1	16.8	16.8
Ubi	7	1.5– 7.1	4.8
Palauan	1	5.8	5.8
Cassava	1	11.7	11.7
Tugi	6	4.4–13.8	10.2

TABLE 3.—*Moisture content of tubers.*

Name.	Number of samples.	Moisture.	
		Range.	Average.
		Per cent.	*Per cent.*
Kamote	4	59.4–62.2	61.2
Ubi	1	76.5	76.5
Yab-yaban	1	68.0	68.0

THE TUBERS AND THE STARCH GRAINS

CONVOLVULACEÆ

IPOMOEA BATATAS (Linnæus) Poiret; Kamote (Tagalog); Sweet potato (English). Plate 1, figs. 1, 2, and 3.

These tubers are obtained from a perennial vine cultivated as an annual for its starchy roots. The boiled leaves are also edible. The average starch content is about 20 per cent but varies according to the variety, the soil, and the climate. This is the most important root crop in the Philippines, of which many native and imported varieties are grown. The yield is given as 10,000 kilograms per hectare.

The starch is easily extracted and settles out well in water, giving a white product. The kamote is one of the promising sources of commercial starch.

Disease, insect pests, and storage rots all affect kamotes in the Philippines, and these facts must be considered when planning large-scale cultivation such as would be required to support a starch industry. Detailed descriptions of these diseases and pests are given by Kingman and Doryland.[12]

The kamote starch grains are either round or dome-shaped, with the hilum distinct and the rings concentric. The size ranges from 4 μ for the smaller grains to 30 μ or more for the larger, with an average of 15 to 18 μ. There are approximately equal numbers of all the sizes. In polarized light the cross is distinct and centric to one-fourth eccentric. The starch was extracted from nineteen samples of kamote.

ARACEÆ

COLOCASIA ESCULENTUM Schott; Gabi (Tagalog); Taro (English). Plate 2, fig. 5; Plate 3, figs. 9 and 10.

The gabi is a perennial aroid cultivated as an annual for its starchy tubers, which are eaten like potatoes. The boiled leaves are also eaten. It is the third most important root crop in the Philippines, ranking next to the kamote and the ubi. The average starch content is about 18 per cent with considerable variation according to the variety.

Kingman and Doryland[13] state that the Philippine Bureau of Agriculture has not encouraged the growing of the gabi because of the productivity of other crops, such as the sweet po-

[12] Kingman and Doryland, Philip. Agr. Rev. 10 (1917) 346–7.
[13] Op. cit. 343.

tato, which can be raised more readily and give greater returns per hectare.

The gabi commonly contains sharp, needlelike crystals of calcium oxalate and must, therefore, be peeled and cooked carefully for eating. These crystals irritate the hands when the tubers are being peeled, ground, and macerated for starch extraction so that it was found advisable to wear rubber gloves when working with them for any length of time.

Gabis, as a rule, are mucilaginous or slimy, and the gummy substance renders the settling and wash waters so viscous that these tubers are generally unsatisfactory as a source of starch, since this condition, in conjunction with the small size of the grains of starch, prevents the latter from settling to the bottom.

One variety of gabi from Cebu (humnao) was found that was an exception to the general rule, as it was not irritating to the skin and was not sticky when worked. The humnao variety has grayish white flesh interspersed with short curly purple veins which resemble the silk threads in bank notes. The juice in water is red. It is easily worked, and the starch settles out well.

Gabi starch ranges from 0.2 μ to as much as 10 μ in size, with about 3 to 4 μ as the average. The grains are small polygons of about five sides; the hilum is sometimes visible on the larger sizes. The polarization cross is dim, but symmetrical or centric with arms at 90° to each other. Twelve samples of gabi starch were prepared.

ALOCASIA MACRORRHIZA (Linnæus) Schott; Biga (Tagalog). Plate 2, fig. 4; Plate 5, figs. 7 and 8.

This species is not cultivated, but the stems and the corms are utilized to some extent as food. Quisumbing,[14] who studied the corms of a two-year old plant, reported that the percentage of starch from fresh stems was 2.75, and from dry ones 18.80.

Four samples of biga starch were prepared. The starch grains are small, irregularly shaped polygons of four or five sides, ranging from 1 μ to 5 μ in diameter and averaging about 3 to 4 μ. The hilum and rings are not visible. The polarization cross is dim, but, as a rule, symmetrical.

CYRTOSPERMA MERKUSII Schott; Palauan (Tagalog); English name not known. Plate 2, fig. 6; Plate 3, figs. 11 and 12.

The large, starchy rootstocks of this aroid are used as food in time of scarcity. The plant is grown to a limited extent in

[14] Philip. Agriculturist and Forester 3 (1914) 85–98.

the Visayas and southern Luzon. The starch content is about 7.5 per cent.

The starch has medium-sized, rounded, and angular-rounded grains from 4 to 18 μ in size, with the average about 11 μ. The grains show pressure facets, resembling a cut stone in many cases. The hilum is visible on very few and is a Y or a straight line. The polarization cross is distinct and is slightly asymmetrical, but centric.

DIOSCOREACEÆ

DIOSCOREA ALATA Linnæus; Ubi (Tagalog); Yam (English). Plate 4.

The ubi is obtained from a widely distributed perennial herb which is cultivated as an annual. There are several distinct varieties in the Archipelago, varying in shape, size, color, and quality of the tubers, ranging from white to dark purple, globose to long and slender. It is the second most important root crop in the Philippines. The average starch content is about 21 per cent with some variation according to variety.

The flesh of ubis has a coarse texture and is very mucilaginous, so that the starch does not settle out at all well in the extraction water. It was found necessary to centrifuge all ubis to make the starch settle out of the slimy liquor.

Twenty-four samples of ubi starch were prepared. The grains are transparent, and may be oval or rounded-triangular, with approximately equal numbers of the different sizes. The smallest ones vary from 8 to 20 μ, and the largest from 33 to 60 μ in length; the average size is about 26 μ wide and 30 μ long. No ring or hilum is visible. The brilliant polarization cross is about one-seventh eccentric with its center near the narrow end of the grain.

DIOSCOREA ESCULENTA Burkill; Tugi (Tagalog); Yam (English). Plate 5.

The tugi is a perennial herb with underground tubers and is cultivated as an annual. There are several well-recognized varieties distinguished by the prevalence and size of subterranean spines, and by the size, form, and quality of the tubers. It is widely distributed but not extensively cultivated. In food quality, the best varieties outrank all other root crops in the Philippines. The average starch content is about 23 per cent.

Eleven samples of starch were prepared from tugis. The tugis worked were slightly mucilaginous, but the starch extracted quite easily and settled out well and in a clean, white condition.

The starch grains are mostly small pentagons, from less than 1 μ to more than 8 μ in size; the average is 4 μ. The smaller

sizes are more numerous, and aggregates of the grains are common. The polarization cross is slightly eccentric. The arms of the cross may be at right angles or not, and one arm may be straight while the other appears curved.

DIOSCOREA PENTAPHYLLA Linnæus; Lima-lima (Tagalog); Yam (English). Plate 6.

Lima-lima is a tuber that may be eaten like potatoes and is obtained from an herbaceous vine. There are two very distinct forms. (See figs. 25 and 26; the leaf of the first has five leaflets, while that of the latter usually has three leaflets.) The average starch content in about 18 per cent.

Three samples of lima-lima starch were prepared. The tubers were only slightly mucilaginous, and the starch settled out well in water. The 3-leaflet specimen contained some black material in the white starch and, as it could not be separated, the final product was gray.

The starch has huge elongated oval or deformed oval grains from 20 μ to as much as 100 μ in length, with 30 to 40 μ as the average size. The rings are distinct, while the hilum is always invisible. A nipplelike form at one end, like that of ginger starch, is found on the grains from the 5-leaflet variety. A conchoidal shape characterizes the 3-leaflet sample. The polarization cross is distinct, striking, and about one-fifteenth eccentric. The intersection is very near the pointed or narrow end of the grain.

DIOSCOREA HISPIDA Dennstedt; Nami (Tagalog); Yam (English). Plate 7, fig. 29; Plate 8, figs. 34 and 35.

The nami is a starchy, poisonous tuber which is rendered edible by immersing the sliced tuber in running water for thirty-six to forty-eight hours. It averages about 18 per cent in starch content with slight variations. There are at least two distinct varieties in the Philippines, one with "hairy" and one with smooth tubers.

One sample of nami starch was prepared. This tuber was very easy to work and gave a milky liquor with the wash water, from which the starch settled very quickly in a clean white state.

The grains are small pentagons with more or less rounded corners ranging from 1 to 4 μ in size and averaging 3.5 μ. Aggregates are common. No hila or rings were observed. The dim polarization cross is centric or very slightly eccentric.

DIOSCOREA LUZONENSIS Schauer; Mayatbang, Kirini, or Pakit (Tagalog); Yam (English). Plate 10, figs. 44 and 45.

This tuber is long and slender; it is not cultivated because of the difficulty in digging it from the soil.

One sample of mayatbang starch was prepared by Dr. H. I. Cole. The grains under the microscope resemble large, round or oval, water-worn rocks and have few hila and no rings visible. They range from 12 to 48 μ in width and from 30 to 67 μ in length; the average is about 26 μ and 35 μ, respectively. The sizes are present in approximately equal numbers. The polarization cross is striking and about one-third eccentric.

DIOSCOREA FLABELLIFOLIA Prain and Burkill; Local names unknown; Yam (English). Plate 10, figs. 40 and 41.

The starch from one sample of this wild tuber was prepared by Dr. H. I. Cole. The grains are smooth triangles with rounded corners and range in size from 12 μ wide and 20 μ long to 27 μ wide and 52 μ long, with an average of 23 μ in width and 30 μ in length. There are fewer of the smaller grains. The rings and the hila are not visible. The polarization cross is about one-seventh eccentric, with the center close to the narrow end of the grain, and very distinct as is usual with the larger *Dioscorea* starch grains.

MARANTACEÆ

MARANTA ARUNDINACEA Linnæus; Aroro (Tagalog); Arrowroot (English). Plate 7, fig. 27; Plate 8, figs. 30 and 31.

This tuber is obtained from a perennial herb from which the arrowroot starch of commerce is made. It is of fairly general distribution but rarely cultivated in the Philippines. The roots contain about 19 per cent of starch.

Two samples of arrowroot starch were prepared. It extracts well and the product is clean and white. The starch grains, which are round or nearly so, are from 8 to 33 μ in diameter; the average is 22 to 25 μ. There is an approximately equal occurrence of all the sizes. The hilum is distinct as a short straight line. Rings are not always evident. The polarization cross is centric to one-third eccentric and very distinct, with unusually broad lines.

EUPHORBIACEÆ

MANIHOT UTILISSIMA Pohl; Kamoting-kahoy (Tagalog); Cassava (English). Plate 9.

This perennial is of universal distribution, but cultivated rarely except in the Sulu Archipelago where it is a staple food. Under ordinary conditions in the Philippines, a conservative estimate of the yield per hectare of merchantable roots from plants

one year old or more is about 25 tons. Average roots contain 25 to 30 per cent starch, about 80 per cent of which is secured in the process of modern manufacture.

The enemies of cassava are few in the Philippines. Old roots left in the ground are often chambered or consumed by insects, but young fresh roots are never attacked. No disease of cassava is known in the Philippines. The principal difficulty in cultivating it is to prevent the ravages of wild hogs.[15]

Twenty-one samples of cassava starch were prepared. The starch extracts easily, settles out well, and gives a clean white product. Cassavas contain cyanogenetic glucosides and are poisonous, but after the tubers have been roasted or boiled properly they are edible.

The starch grains are round and dome-shaped and resemble kamote (sweet potato) starch but are smaller. The hilum is distinct, with the form of a Y or a very flat V like the wings of a flying bird. The rings are faint. The grains range from 3 to 20 μ in size; the average is about 11 μ. Approximately equal numbers of the sizes are found. The polarization cross is distinct, symmetrical, and centric, with the arms at right angles to each other.

TACCACEÆ

TACA PINNATIFIDA Forester; Yab-yaban (Tagalog); Polynesian or East Indian arrowroot (English). Plate 7, fig. 28; Plate 8, figs. 32 and 33.

This plant has somewhat rounded or oval tubers up to 8 centimeters in diameter, perhaps larger in rich soil. Bacon [16] found that the tubers yielded 22.3 per cent of very pure starch, which was easily extracted. It is known in commerce as Polynesian or East Indian arrowroot starch. The plant, however, is apparently little utilized in the Philippines and is never cultivated. The starch must be washed several times to eliminate the bitter principle found in the fresh tubers.

One sample of yab-yaban starch was prepared from a sample submitted by an official of the Bureau of Commerce and Industry, who was interested in the commercial possibilities of this starch in the Philippines. An analysis was made with the following results:

Moisture, per cent	68
Starch, on wet basis, per cent	24.03
Starch, on dry basis, per cent	75.1
Cyanogenetic glucosides	None
Alkaloids	None

[15] Kingman and Doryland, Philip. Agr. Rev. 10 (1917) 338–340.
[16] Philip. Journ. Sci. § A 3 (1908) 96.

The starch was determined by the acid hydrolysis method and Fehling's solution [17] as follows:

The tuber was peeled and ground in an ordinary kitchen food chopper, and approximately 10 grams of the pulp were weighed into a beaker to which 50 cubic centimeters of water were added. The mixture was allowed to stand with occasional stirring for an hour, then filtered, and the pulp washed with ether and alcohol. When the filtrate was cloudy it was centrifuged, and the solid matter so obtained, together with the filter paper and its contents, was placed in a reflux apparatus with 200 cubic centimeters of water and 20 cubic centimeters of dilute hydrochloric acid (specific gravity, 1.125), after which it was heated (reflux) for two and one-half hours. The contents of the flask were then cooled, neutralized with sodium hydroxide, and the volume diluted to 500 cubic centimeters. The solution was filtered, and the dextrose in a 25 cubic centimeter portion was determined by Fehling's solutions. The precipitated cuprous oxide was dissolved and the copper checked electrolytically. Leach gives tables converting the weight of copper obtained to the weight of dextrose present.[18] Taking 0.9 as the factor for converting dextrose to starch, then—

$$\frac{\text{Weight of dextrose} \times 0.9 \times 500 \times 100}{25} = \text{Per cent of starch.}$$

The grains of yab-yaban starch are round or horseshoe-shaped with the hilum distinct as a short straight or wavy line. They resemble the grains of kamote starch but are slightly larger. The rings are visible on larger grains. The size ranges from 8 to 40 μ, with 20 μ as the average. A lesser proportion of the smaller sizes is observed. The brilliant polarization cross is centric to one-half eccentric; one arm is often curved.

CYCADACEÆ

CYCAS sp. A cycad indigenous to Culion Island. Plate 10, figs. 42 and 43.

This cycad is an undescribed species. It has a pithy, starchy core which fills most of the trunk, while the outside wood is simply a shell. This species does not occur in quantity sufficient to be of commercial importance.

[17] Leach, A. E., Food Inspection and Analysis (1907); and United States Department of Agriculture, Bureau of Chemistry Bulletin No. 107, Revised, Official and Provisional Methods of Analysis, Association of Agricultural Chemists (1925) 119.

[18] Op. cit. 493–495, under Allihn's method for the determination of dextrose.

Starch was prepared from one sample of this cycad. The hard, thin outside was peeled off and the pithy core ground and treated as in preparing the starches from tubers. The small pieces of ground core are rather hard, so that fine grinding is essential to a good recovery of starch.

The starch grains are round, with distinct hilum showing as a cross, a Y, or a straight line. The size of the grains ranges from 3 to 19 μ, with an average size of 11 to 14 μ. The smaller ones are more numerous. The polarization cross is distinct, symmetrical, and centric, with arms at 90° to each other.

DISCUSSION OF RESULTS

Kamote, yab-yaban, aroro, nami, and kamoting-kahoy starches were all found easy to extract in pure, white form by methods such as would be used commercially. These plants have potential economic value as sources of commercial starch in the Philippine Islands.

Starches from tugi, lima-lima, and the trunk of a new cycad were prepared with only slight difficulty.

As a rule, the larger the grains of a starch, the more easily it is extracted and washed. The ubi is an exception as it is so mucilaginous that the starch grains, although relatively large, settle very slowly out of the viscous mother liquor. Gabi and biga are also difficult to work as the starch grains are small and the tubers are mucilaginous.

Mayatbang and lima-lima starches have relatively huge grains, averaging some 40 to 50 μ in length. The latter is distinguished by distinct rings and a nipplelike protuberance at one end of the grain or by a curved cornucopia shape. In polarized light the cross has a much greater eccentricity than that of mayatbang.

Dioscorea flabellifolia, aroro, yab-yaban, ubi, and kamote starches have medium-sized grains of the order of 20 to 30 μ. Aroro and yab-yaban are round and similar, but the latter is distinguished by the presence of a few oval grains with flattened ends like a horseshoe, together with a slightly smaller average size of grains. *Dioscorea flabellifolia* starch resembles closely that of ubi, particularly since the latter varies somewhat in different plants. Rings are evident on the former and not on the latter. The ubi polarization cross shows slightly less eccentricity. Kamote starch is readily distinguished from any of the above starches by its combination of round and dome-shaped grains, distinct hilum, and only slightly eccentric polarization cross.

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TABLE 4.—*Morphological characteristics of the starch grains.*

Names.	Length.		Appearance.	Rings.	Hilum.	Sizes.	Polarization cross.
	Extremes.	Average.					
	μ	μ					
Kamote; sweet potato; *Ipomea batatas.*	4–30	15–18	Round or dome-shaped; fissures common; convex.	Faint	Distinct line, V or Y	Equal numbers	Brilliant; centric to 1/4 eccentric.
Biga; *Alocasia macrorrhiza.*	1–5	3–4	Four- or 5-sided polygons; smooth.	None	None	do	Dim; symmetrical.
Gabi; taro; *Colocasia esculentum.*	0.2–10	3–4	Four- or 5-sided polygons; smooth; pressure facets.	do	Visible on large grains	do	Dim; centric; symmetric.
Palauan; *Cyrtosperma merkusii.*	4–18	11	Round or angular rounded; pressure facets.	do	Few	do	Distinct; centric; slightly asymmetric.
Ubi; yam; *Dioscorea alata.*	8–60	30	Oval or rounded triangular; smooth; transparent.	do	None	do	Brilliant; eccentricity 1/7.
Tugi; yam; *Dioscorea esculenta.*	1–8	4	Pentagons; smooth; pressure facets.	do	do	Less large grains	Dim; eccentricity slight; one arm often curved.
Lima-lima (3-leaved); yam; *Dioscorea pentaphylla.*	20–100	30–40	Conchoidal; convex	Distinct	do	Less small grains	Brilliant; eccentricity 1/15.
Lima-lima (5-leaved); yam; *Dioscorea pentaphylla.*	20–100	30–40	Oval with nipple at end; flat; smooth; translucent.	do	do	do	Do.
Aroro; arrowroot; *Maranta arundinacea.*	8–33	20–25	Oval or round; convex	Rarely visible	Distinct as short line	Equal numbers	Brilliant; broad lines; centric to 1/3 eccentric.

Yab-yaban; East Indian arrowroot; *Tacca pinnatifida.*	8–40	20	Round or horseshoe-shape; convex.	Visible on larger grains.	----do----------	Less small grains--	Brilliant; centric to 1/2 eccentric; one arm often curved.
Nami; yam; *Dioscorea hispida.*	1–4	3.5	Pentagons with rounded corners; pressure facets.	None----------	None----------	Equal numbers----	Dim; centric.
Kamoting-kahoy; cassava; *Manihot utilissima.*	3–20	11	Round and domeshaped; convex; fissures; pressure facets.	Faint----------	Distinct as Y or flat V	----do----------	Distinct; centric.
Dioscorea flabellifolia ----	20–52	30	Rounded triangles; flat; smooth.	None----------	None----------	Less small grains--	Brilliant; eccentricity 1/7.
Cycas sp., from Culion--	3–19	11–14	Round; convex; smooth.	----do----------	Distinct stellate Y or short line	More small grains.	Distinct; centric; symmetrical.
Mayatbang; yam; *Dioscorea luzonensis.*	30–67	35	Round or oval; rough; convex.	----do----------	Few----------	Equal numbers----	Brilliant; eccentricity 1/3.

Among the smaller medium-sized starch grains, of the order of 10 to 12 μ, are those from kamoting-kahoy, the Culion cycad, and palauan. Kamoting-kahoy starch resembles the starch from kamote and may easily be mistaken for it, but the grains are smaller and show a symmetrical, centrally located cross in polarized light. The starch of the Culion cycad resembles that of kamoting-kahoy but has more uniformly rounded grains and a greater proportion of the smaller sizes. Palauan starch is distinguished by the ubiquitous pressure facets of the grains. It bears a superficial resemblance to corn starch but exhibits a more uniform and regular shape.

Nami, tugi, biga, and gabi starch grains are extremely small polygons of four or five sides, about 3 or 4 μ in diameter, and would be almost impossible to differentiate in a mixture by their appearance.

SUMMARY

Fourteen varieties of starches were prepared from one hundred two Philippine plant samples. Descriptions and photomicrographs are given as well as photographs and data of the tubers and plants from which the starches were obtained.

In general the several starches show marked physical differences which are recognizable in the photomicrographs.

The histological characteristics of various samples of starch prepared from the same plant species are remarkably constant and are practically independent of locality and growing conditions.

ILLUSTRATIONS

PLATE 1

FIG. 1. Kamote (sweet potato) starch.
2. Kamote starch in polarized light.
3. Kamote tubers.

PLATE 2

FIG. 4. Biga corms.
5. Gabi (taro) corms.
6. Palauan rootstock.

PLATE 3

FIG. 7. Biga starch.
8. Biga starch in polarized light.
9. Gabi starch.
10. Gabi starch in polarized light.
11. Palauan starch.
12. Palauan starch in polarized light.

PLATE 4

FIG. 13. Ubi (yam) starch.
14. Ubi starch in polarized light.
15. Ubi tuber.
16. Ubi tubers.

PLATE 5

FIG. 17. Tugi (yam) starch.
18. Tugi starch in polarized light.
19. Tugi tubers.
20. Tugi tubers.

PLATE 6

FIG. 21. Lima-lima (yam) starch, 5-leaflet variety.
22. Lima-lima starch, 5-leaflet variety, in polarized light.
23. Lima-lima starch, 3-leaflet variety.
24. Lima-lima, starch, 3-leaflet variety, in polarized light.
25. Lima-lima tubers, 5-leaflet variety.
26. Lima-lima tubers, 3-leaflet variety.

PLATE 7

FIG. 27. Aroro (arrowroot) rhizomes.
28. Yab-yaban (East Indian arrowroot) tubers.
29. Nami (yam) tubers.

PLATE 8

FIG. 30. Aroro starch.
31. Aroro starch in polarized light.
32. Yab-yaban starch.

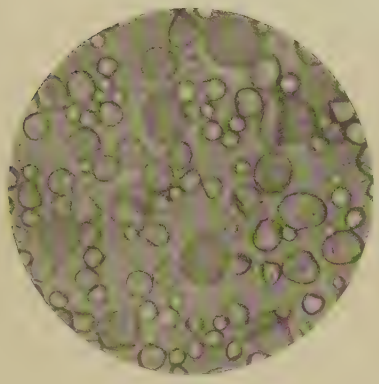
FIG. 33. Yab-yaban starch in polarized light.
34. Nami starch.
35. Nami starch in polarized light.

PLATE 9

FIG. 36. Kamoting-kahoy (cassava) starch.
37. Kamoting-kahoy starch in polarized light.
38. Kamoting-kahoy roots.
39. Kamoting-kahoy roots.

PLATE 10

FIG. 40. *Dioscorea flabellifolia* (yam) starch.
41. *Dioscorea flabellifolia* starch in polarized light.
42. *Cycas* sp. starch.
43. *Cycas* sp. starch in polarized light.
44. Mayatbang (yam) starch.
45. Mayatbang starch in polarized light.



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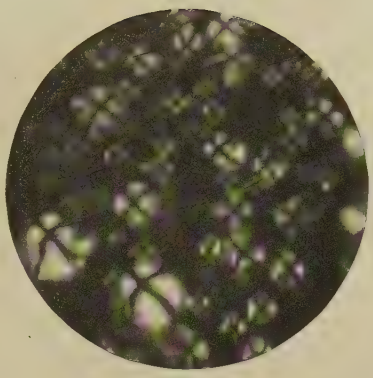

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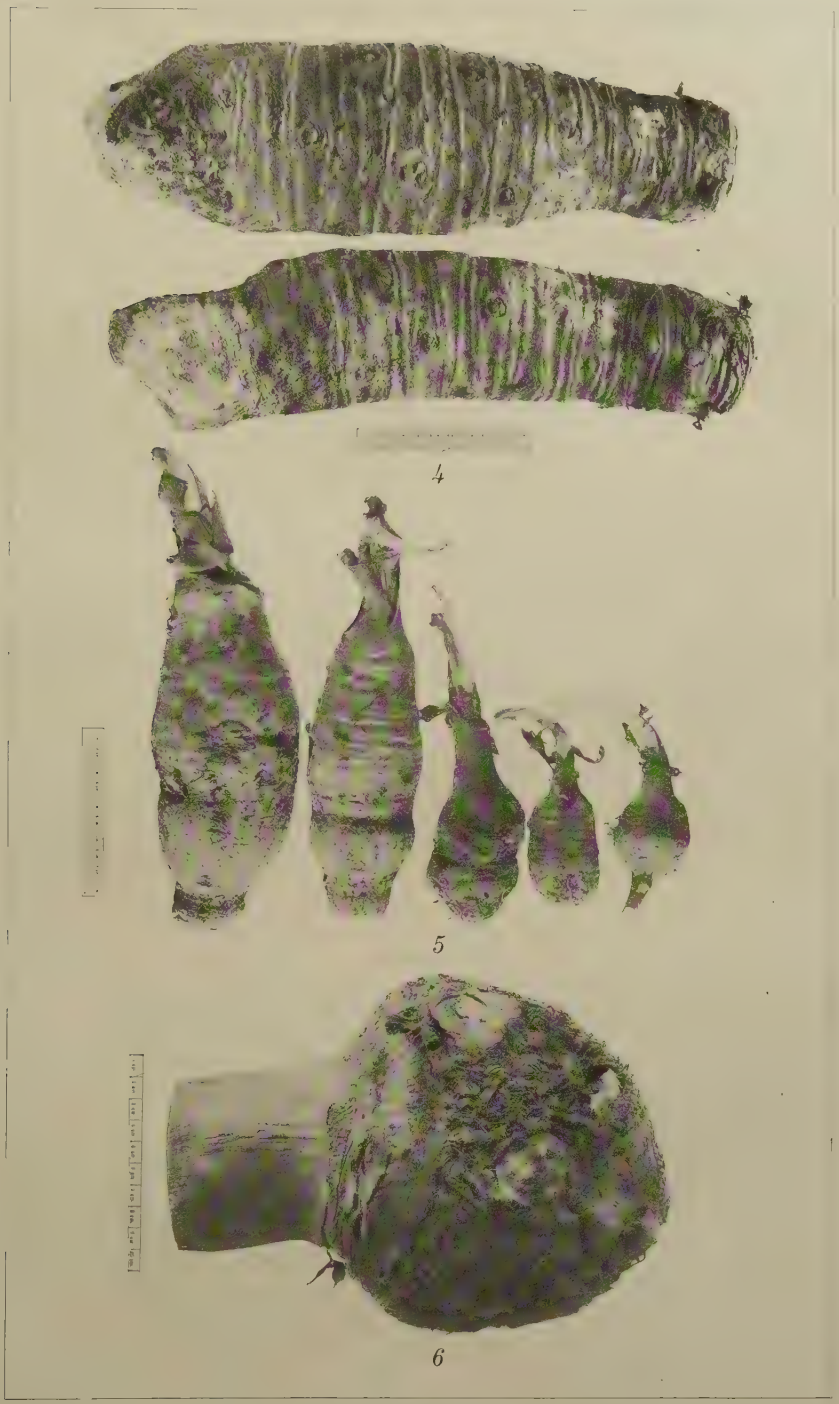

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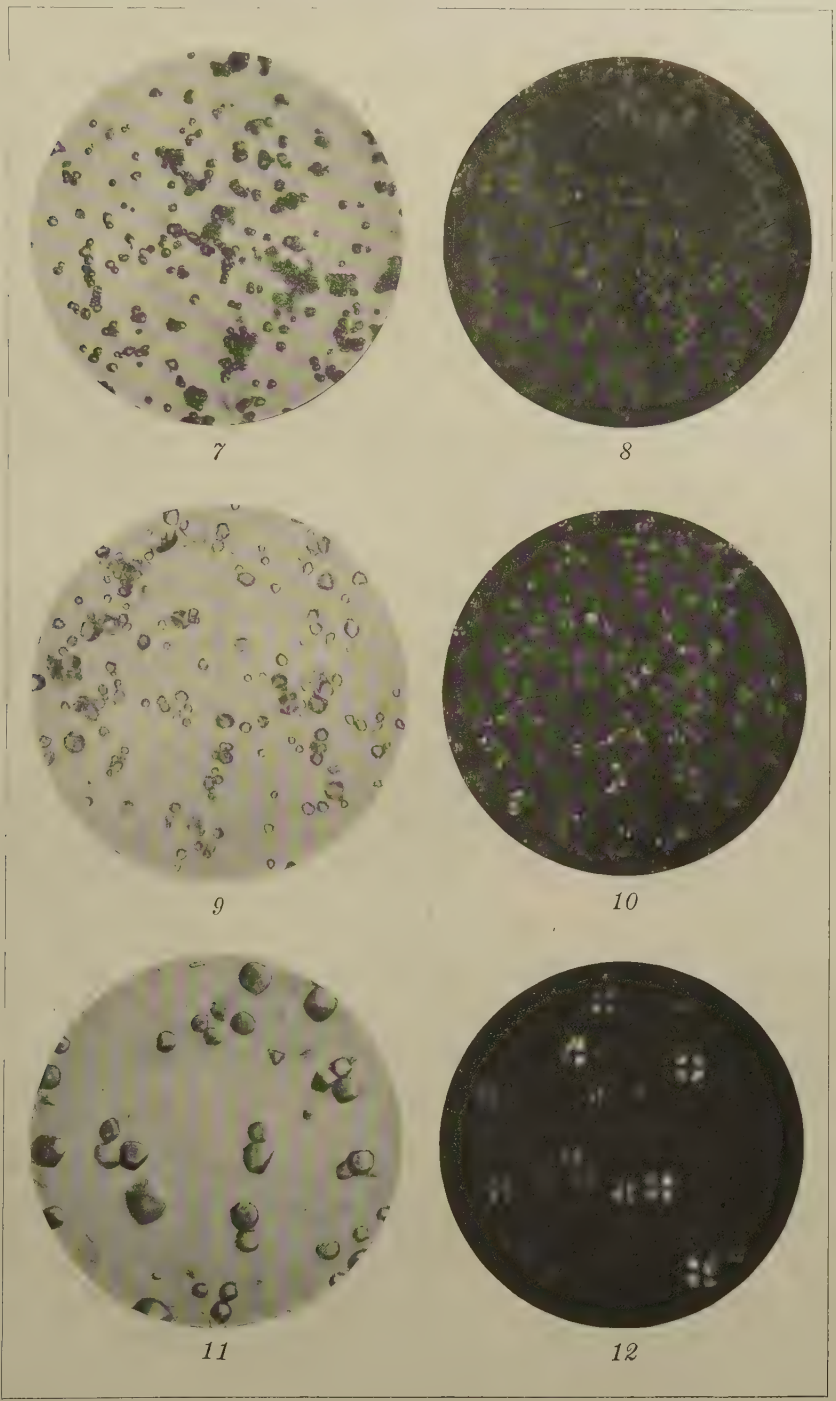

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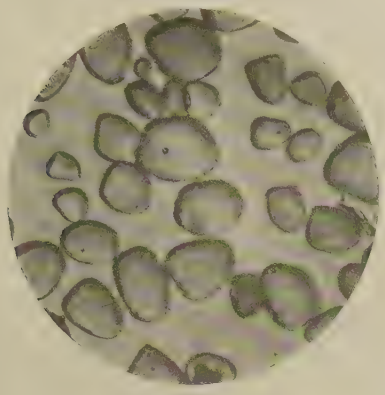

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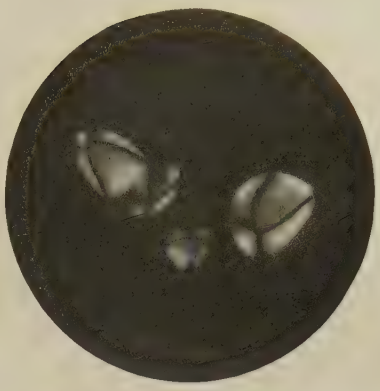

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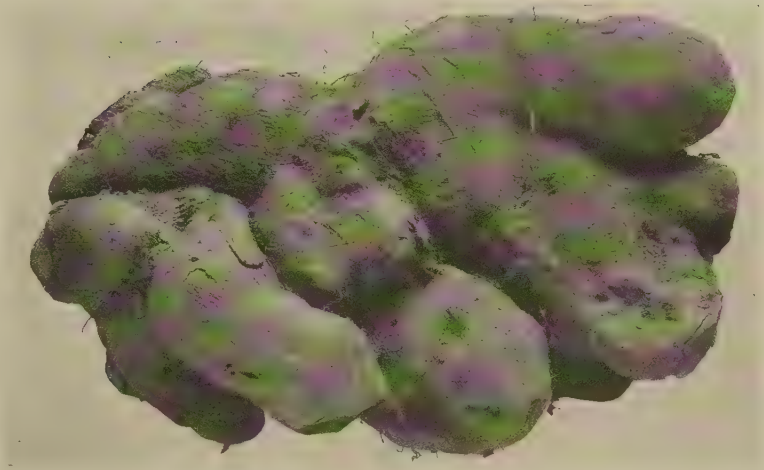

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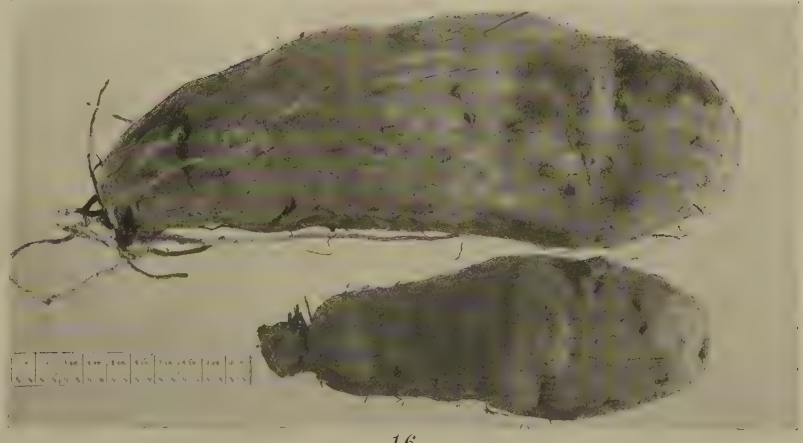

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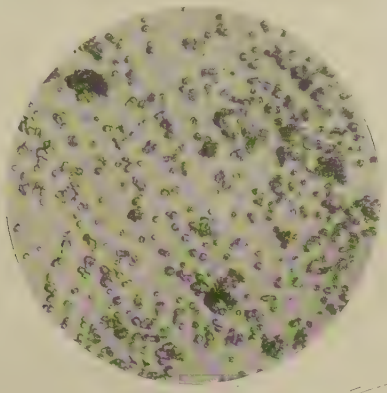
PLATE 4.



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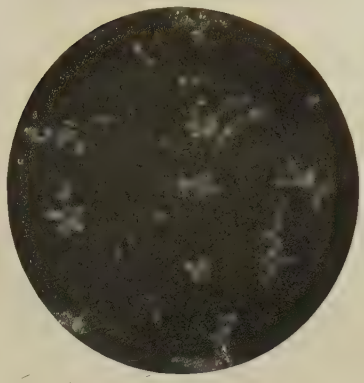

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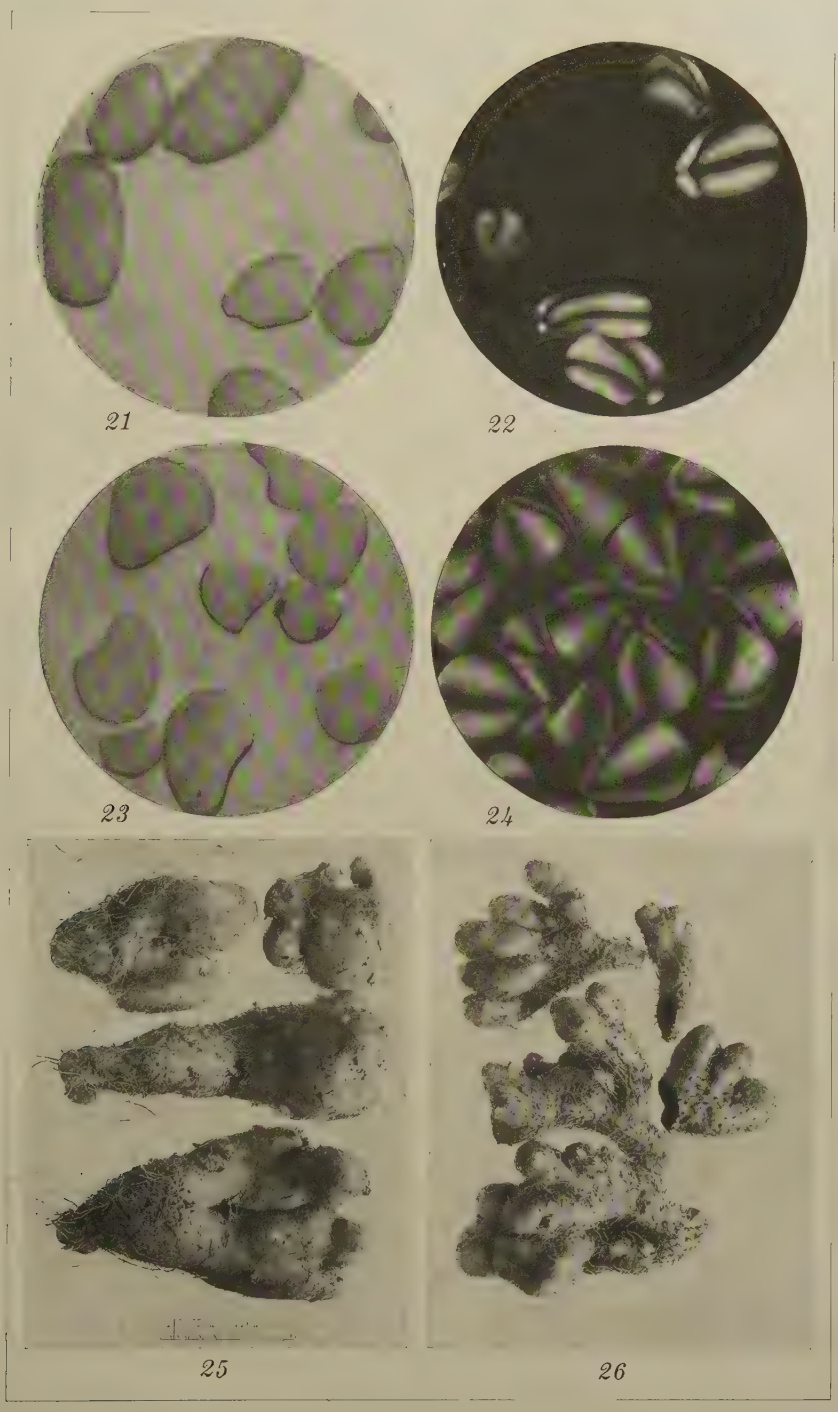

PLATE 6.

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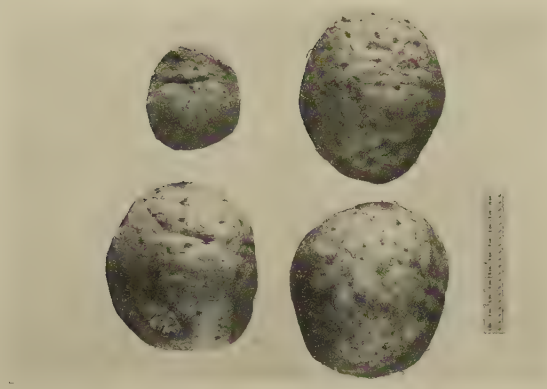

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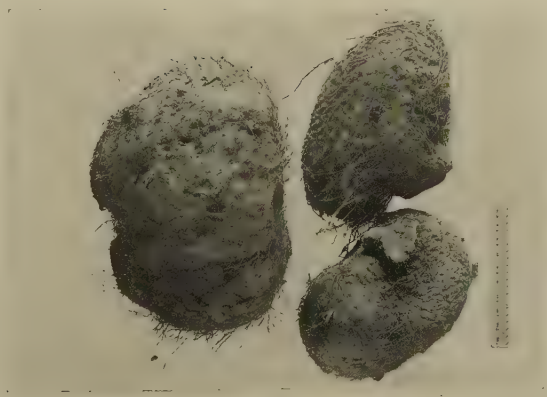

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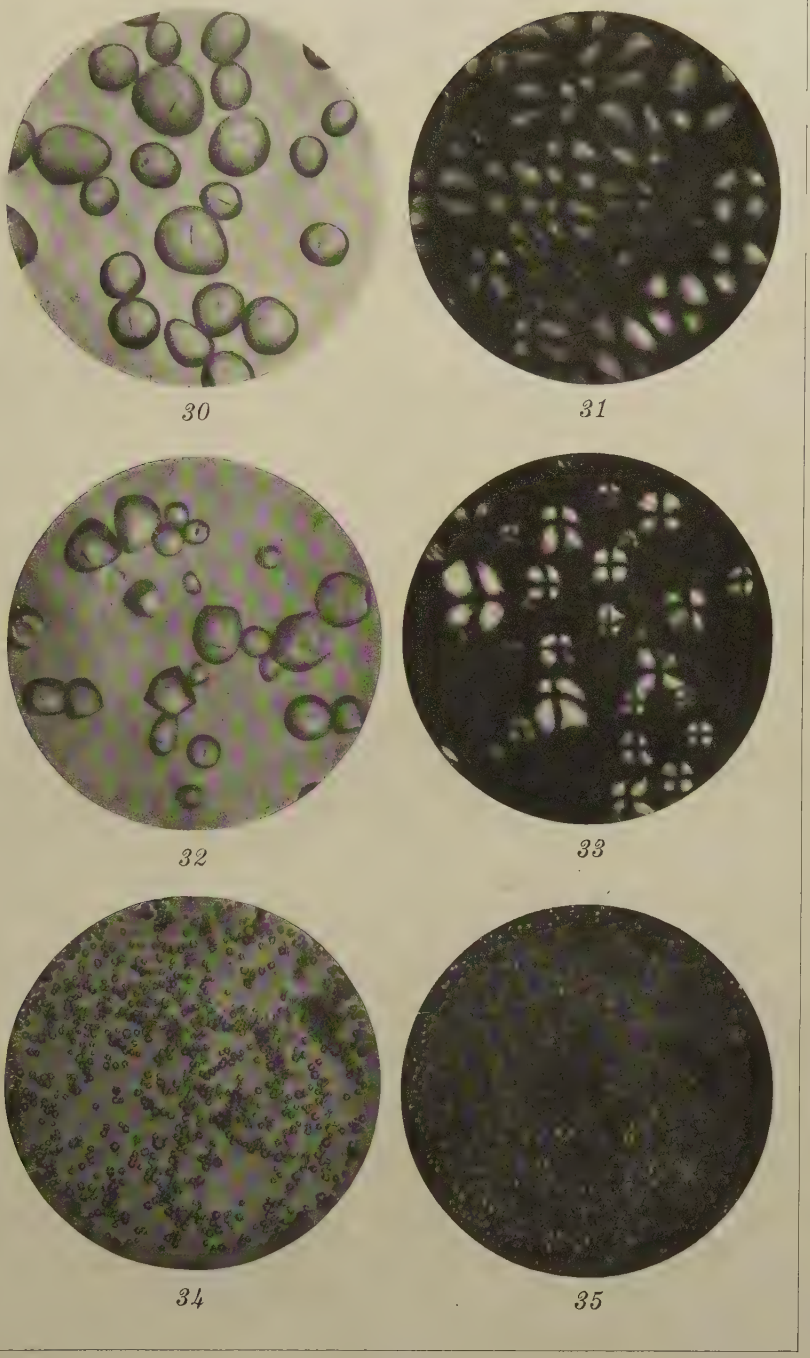

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PLATE 8.

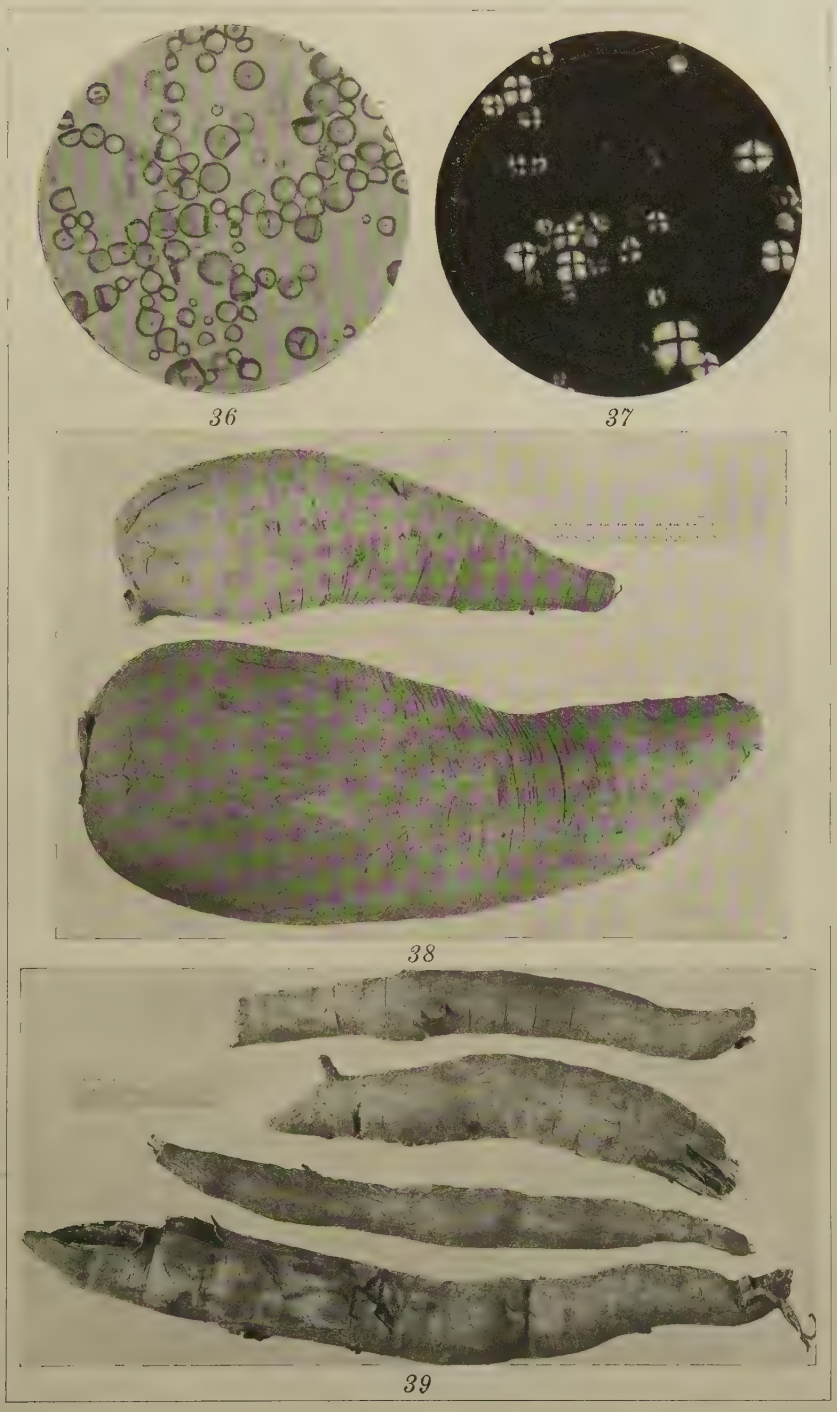

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PLATE 9.

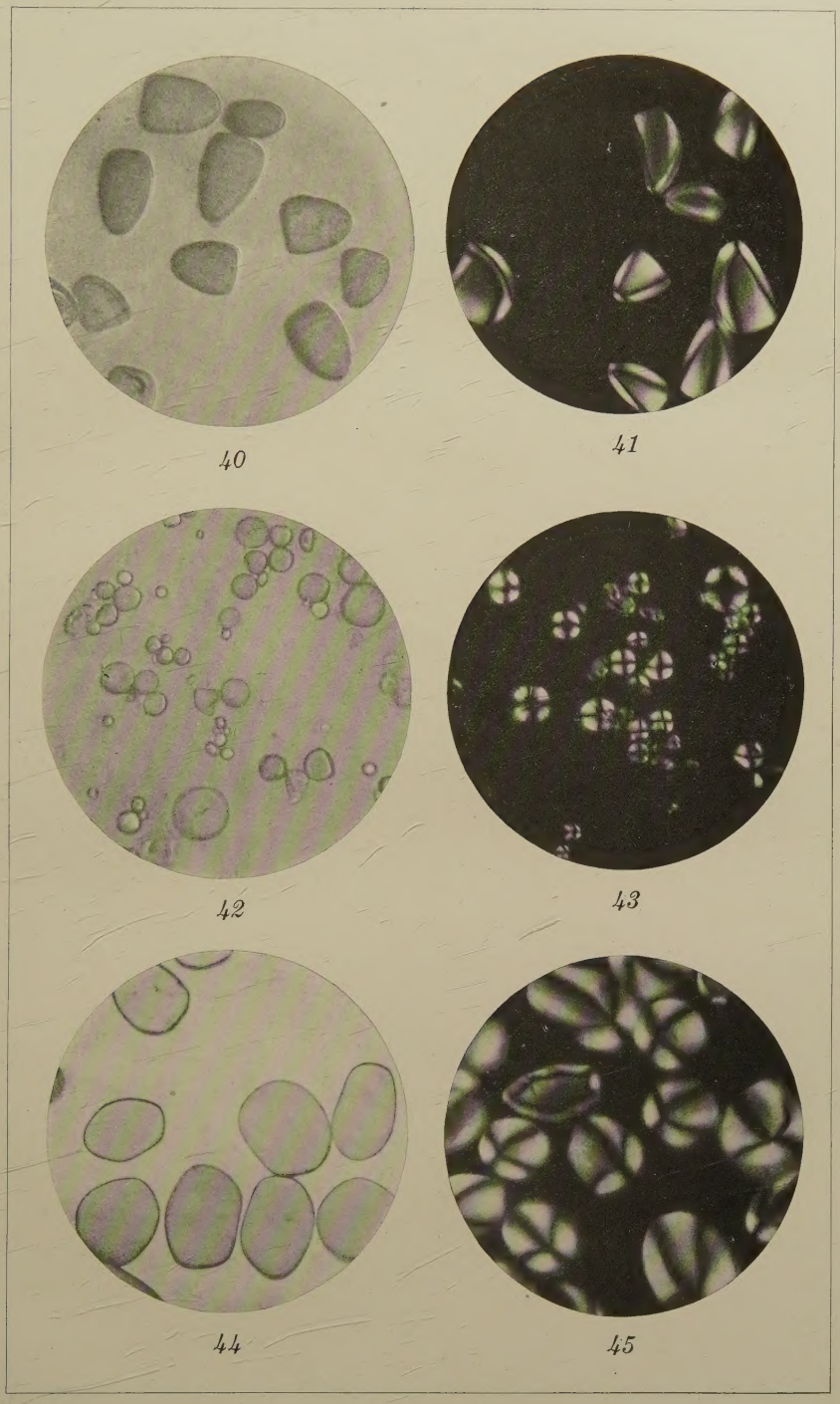

PLATE 10.